INTEGRATED NATURAL RESOURCE CONSERVATION ON WATERSHED BASIS FOR INCREASING PRODUCTIVITY

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CERTIFICATE

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CHAPTER-1

INTRODUCTION

INTRODUCTION

In arid and semi-arid areas, crops are often subjected to unpredictable periods of high moisture stress between rains or to increasing moisture stresses as the soil moisture reserve gets progressively depleted. Too frequently, the plant has a finite amount of water on which it can draw and then whether it withers and dies or survive depends on its inherent capacity for its drought tolerance. About 62 per cent of India's cropped land is under rainfed condition which countribute 40 per cent of the country's total food grain production. This signifies the importance of management of rainfed lands for crop production. The rainfall in these regions is often insufficient, erratic and unevenly distributed. Under such situation, the success or faliure of the crop depends entirely on the amount of soil moisture conserved by the farmer before crop sowing and or occurence of rains before the sowing season.

The productivity of rainfed agricultural lands in the semi- arid areas is specially low because of raising more than one crop is often limited because of low rainfall availability for more than one crop. Thus the cropping intensity is often less than 100 per cent in semi-arid areas. The situation thus calls for adoption of appropriate moisture conservation measures which will help *in-situ* moisture conservation and gives an opportunity to raise a decent crop.

Management of rainfed agricultural lands on a scientific principle could be tackled through the treatment of a given hydrologically defined unit area in a holistic manner (Bali, 1988). The given or defined hydrological drainage area having a common draining point and differentiated from the adjacent area on the ridge line is called 'Watershed'. The treatment and its further management entailing the area to be developed for suitable use of plant production is most sound scientific proposition in drier areas. This not only helps in managing rainfall resources for its *in-situ* conservation but also with the adoption of appropriate soil conservation measures helps in storage and conservation of rain water in ponds, ani-cuts, check dams for its further use. This also greatly helps in reacharge of ground water substantially for its exploitation for crop production.

The soil and water conservation measures which is so adopted not only help *in-situ* conservation of rain water and collection of rain water in detention areas but also have a great-value in protecting natural resources like soil and water losses through erosion. This further leads to protection of soil and also conservation of bio- diversity on its surface, regeneration of useful range and other plant species which are either lost or in the process of extinction due to continuous erosion of soil.

Improvement in soil moisture regime over a period of time due to adoption of soil and water conservation practices further help in regeneration of soil productivity which is further conducive to the development of plants of higher order in utility (Hazra, 1997).

Watershed management is thus a holistic approach harmonises and development of lands for appropriate plant and animal production thereby helps in improving the economy of the farmer (Das, 1993). Sustainable development of agricultural land is only possible through the real sense management of land on watershed basis.

As the watershed is viewed is the holistic development of rainfed lands, it is equally important to study the effect of activities relating to different soil and water conservation measures on resource conservation and primary resource regeneration specially water availability. Which is essential for plant production. It is also all the more important to make studies on the effect of various component of crop production on the changing soil water availability situation. The 'on-farm' responses under actual field situation on various agronomic measures which will help in efficient use of increased rain water resources and also managing other agronomic measures which will ultimately be reflected on the increased crop yield is very important and need to be intensively studied. It is also important to study the direct effect of any soil conservation practices on crop/plant production apart from other indirect influences.

As the watershed development programmes is envisaged a holistic development, the direct and indirect gains to the community or the farmers in the form of animal production for raising standard of living and farm income is equally important. The management of recreated and regenerated resources for sustained productivity and its management for sharing the benefits equitably are also equally important so that the resources so created is effectively being used and managed by the community on long term sustained basis.

Thus the present study entitled. "Integrated natural resource conservation on watershed basis for increasing productivity", was taken up at the Tejpura village of Jhansi district in Uttar Pradesh with the following objectives:

1. To conserve, improve and utilise natural resources in a most harmonious and integrated manner;
2. To improve the crop production evironment and restoration of ecological balance through scientific management of land and rainwater;
3. To reduce the disparity/inequalities between irrigated and rainfed through appropriate intervention of crop production technologies;
4. To study the impact of soil and water conservation measures on crop/plant production;
5. To study the effect of various agronomic measures on crop production in the watershed;
6. To regenerate natural resource through soil and water conservation for fuelwood and forage production for increased milk production;
7. To find out ways and means for alternative employment for landless people of the watershed and increased income;
8. To study the cost-benefit and other socio-economic aspects of the watershed ; and
9. To develop village level groups/institutions for managing the created and regenerated resources in the watershed for sharing usufruct benefits and managing and protecting the sharable natural resources;

CHAPTER-2

REVIEW OF LITERATURE

Watershed management - The basis for integrated development

By and large, most of the arid and semi-arid regions have been overlooked in the past. It is only in recent years, little attention has been paid to the problem of these areas. These re gions have concentrations of eroded and degraded natural resources. Loss of vegetative cover followed by soil degradation through various forms of erosion has resulted in lands which are thirsty in terms of water as well as hungry in terms of soil nutrients. All these regions have predominately livestock-centered farming systems; less biomass for animals not only reduce animal productivity but subsequent intense grazing pressures on already eroded lands further exacerbate the problem and deteriorate the ecological balance. Growing population pressure, higher demand for food and fodder coupled with impact of rapidly changing socio-economic condition have added fuel to the fire. The piecemeal approaches such as contour bunding or terracing on individual holdings or a group of farms only marginally benefit as they are done ignoring to what happens to other areas which are influencing the hydrologic characteristics. Such sporadic actions generally fail to attract farmers too as they do not yield benefit commensurating with the efforts and investments made.

Of the 117 million hectares (M ha) of the rainfed crop lands of India, water is the issue. Its flow causes soil erosion, gullying, water logging and sedimentation. The scarcity of water causes droughts. Excess of water causes floods and drainage problems. Water is not only a product of the rainfall but also of the land. Only when rainfall and land interact, runoff water is produced. Water which infiltrates into the soil produces plants or recharges ground water which can again be drawn up to grow plants. Land, water, plants and animals are closely inter-related which can best be managed in an integrated way within a watershed. Thus, for maximising the advantages, all developmental activities should be undertaken in a comprehensive way on watershed basis. The main principles of watershed management as outlined by Singh *et al* (1990) are :

i) utilizing the land according to its capability,

ii) putting adequate vegetal cover on the soil during the rainy season,

iii) conserving as much rain water as possible at the place where it falls,

iv) draining out excess water with a safe velocity and diverting it to storage ponds and store it for future use,

v) avoiding gully formation and putting checks at suitable intervals to control soil erosion and recharge ground water,

vi) maximising productivity per unit area, per unit time and per unit of water,

vii) increasing cropping intensity and land equivalent ratio through intercropping and sequence cropping,

viii) safe utilization of marginal lands through alternate land use systems,

ix) ensuring subtainability of the eco-systems befitting the man- animal- plant-land-water complex in the watershed,

x) maximising the combined income from the inter-related and dynamic crop-livestock-tree-labour complex over years,

xi) stabilising total income and cut down risks during aberrant weather situations; and

xii) improving infrastructural facilities with regard to storage, transportation and marketing.

Watershed management is a holistic approach aimed at optimising the use of land, water and vegetation in an area and therefore could help alleviate drought, moderate floods, prevent soil erosion, improve water availability, increase fuel, fodder and agricultural production on a sustained basis (Dhouvanaryana and Rambabu, 1983). Watershed management (as defined by Bali, 1988) means harmonious development and management of land and water within the natural boundaries of a watershed so as to produce, on a sustainable basis, abundance of plants and animals for the good of man, and still deliver clean and controlled flow of water to the downstream.

A watershed management programme should have the following two type of components:

(i) *Hardware (core or foundation) component of soil and water conservation works*

These practices include conservation land treatment (bunding, trenching, terracing, vegetative barriers, grass waterways etc.) and water harvesting structures (ponds, ani-cuts, wells, water channels or pipes, stop dams etc.) and water surplusing and grade stabilisation structures (waste weirs in bunds, spillways, rockfill dams, gully plugs etc) and land shaping and levelling.

(ii) *Software (superstructure) component of conservation or sustainable production systems*

These include conservation farming, forestry, agrostology, plantation, aquaculture, animal husbandry production systems or any mix of the above as suited to the physical, socio-economic and biological conditions within a watershed.

On dryland agriculture irrigation means soil and water conservation especially the water development component (which is usually down played as a mere engineering measure) and unless water harvesting and agronomic practices are combined, production on the drylands cannot be made an assured source for the nation and the 400 million people who derived their livelihood from the rainfed lands. Only water harvesting (which should include groundwater development also at the micro level) plus land shaping and levelling would constitute effective soil conservation measures for the intensive land use scenario of the 21st century when more and more would have to be produced from less and less of land.

Any land which does not produce the maximum sustainable quantities of useable materials is wasteland or wasted land. To some degree major chunk of the land (175 M ha) in India is wasteland. In its preventive concept, wasteland becomes synonymous with soil and water conservation and watershed management. In fact, land care and conservation on lines of watershed management would be the host programme of wasteland development (Bali, 1997).

According to All India Soil and Land use Survey, watershed Atlas, 1990, the whole country has been demarcated into 6 water Resource Regions (Indus drainage, Ganges drainage, Brahmputra drainage, All drainage flowing into Bay of Bengal except those at Ganges and Brahmputra, All drainage flowing into

Arabian Sea except those at Indus, and Western Rajasthan mostly emphemeral drainage), 35 River Basins, 112 Catchments and 3237 watersheds.

2 Natural Resource Conservation

The natural resources bestowed by nature upon mankind include air, land, water, forests, animals, minerals, petroleum, wildlife and marine wealth. The lives of the poor, in particular, are intricately related with natural resource based activities, such as agriculture, horticulture, and animal husbandry which form the basic source of livelihood for more than two third of the work force. The natural resource management sector has been and continues to be, the mainstay of the Indian economy. The poor in India are mainly concentrated in the five states of Bihar, Orissa, Madhya Pradesh, Rajasthan and Uttar Pradesh, and account for 40% of the country's population. These communities generally have very limited access to land and control over forests and water resources (including fuelwood and drinking water), which play a vital role in their economic development.

Soil and water are the basic resources essential for survival of human being on earth. According to Dr. H.H. Bennett, "Soil without water is desert and water without soil is useless". Transformation of rocky earth's crust into the soil by weathering is a very long process. It is estimated that it takes anything from 400 to 1000 years for formation of just 2.5 cm of top soil. Left to nature, the soil is protected by natural vegetation. Under undisturbed conditions, geological erosion under natural conditions of "adrading' and 'aggrading' is well balanced". thus, a state of equilibrium is reached between climate, soil, rainfall, land, slope and vegetative cover. Because of human interference, the protective shield of land is disturbed and the land is torn into pieces by the erosion process - starting from splash erosion to formation of gullies and ravines. Man's ever increasing needs and greeds resulted in the over exploitation of nature's gift and indiscriminate use of land resources and felling of trees and removal of grasses. As a result, erosion problem has assumed threatening dimensions. It is estimated that about 175.06 million hectares (M ha) of land in India is suffering from soil erosion and land degradation (Mukherjee *et al* 1985). Area subject to water erosion is about 111.30 M ha and an area of 38.70 M ha is affected by wind erosion. About 25.06 M ha is also affected and degraded through special problem like waterlogging (6.00 M ha), salinity and alkalinity (8.00 M ha), ravines and gullies (3.97 M ha), shifting cultivation (4.36 M ha) and raverine and torrents (2.73 M ha). It is also reported that the country looses soil nutrients to the tune of 8.4 million metric tonnes (Mt) because of soil and water losses (Hazra, 1996).

In India, land is being eroded at an averatge rate of 16.35 t/ha/year which is far more than the highest tolerance limit of 12.5 t/ha/year (Mannering, 1981) many land management systems, such as cultivation of steep slopes, shifting cultivation etc result is much higher rate of soil loss. A joint study of FAO, UNFPA and IIASA established a relationship between the soil erosion rate and the decline in land productivity and the results revealed that if soil loss is more than 12 t/ha/year the lands start getting down graded in terms of productivity; if it is between 12 and 15 t/ha/year, 50% of the area of very productive land down grades to just productive land; if the rate of soil loss is between 50 and 100 t/ha/year, 100% of all productive land down grades by one productivity class; if the rate is between 100 and 200 t/ha/year, 50% of all productive land down grades to not suitable/non-productive land. About 60 Mt, comprising 10% of total annual soil loss finds place into the reservoirs (resulting in loss of storage capacity of 1-2% per year). While 29 per cent drains into sea and 61 per cent shifts on land from one site to the other (Narayana, 1993).

Through suitable soil and water conservation measures, both mechanical and vegetational, these lands could not only be rehabilated but could also provide the much needed food, fodder, fuel on sustainable basis by reducing the present stupendous amount of loss in natural resources to safe permissible level.

3 Soil and Water Conservation measure

Soil and water are the basic resources and must be conserved as carefully as possible. In the words of Lord John Boyd Orr, The first Director-General of FAO in 1948, "increase in agricultural production are possible through modern methods. But these advances in science will be useless, unless there is enough good land for farming. If the soil on which all agricultural and all human life depends is wasted away then the battle to free mankind from want cannot be won". The top soil is our supporting layer and it is upon the productiveness of this layer that our survival and prosperity depends. Run-off being the single most important agent of soil erosion so far arable land is concerned and therefore, its efficient management plays the key role in all soil and water conservation practices. When and how much rainfal occurs is uncontrollable. However, in the future, more upland erosion and sediment yield control plans will probably be based on the probability of extreme erosion events (Woolhiser and Blinco, 1975; Simons *et al,* 1977; Fogel *et al,* 1977) so that erosion may be reduced by planning crops or managing land use in such a way that soil disturbing activities are perfomed during period of lesser erosive rains.

Some soils are naturally more susceptible to erosion than other (Wischmeier and Mannering, 1969). A highly erodible soil may erode 10 times faster than a less susceptible soil exposed to the same moderate to intense rainfall (Wischmeier *et al,* 1971). Soil properties influencing soil erodibility include primary particle size distribution, organic matter, soil structure, iron and aluminium oxides, electrochemical bonds, initial moisture content, and wetting agents (Wischmeier *et al,* 1971; Grissinger, 1966; Roth *et al,* 1974; Partheniades, 1972, Hazra, 1995).

3.1 Mechanical measures

The mechanical measures include earth moving and land shaping practices which are closely linked with the choice of land-use and land-capability classification. Mechanical measures consist of construction of meachanical barriers across the direction of the flow of water to retard or retain the runoff and thereby reduce soil and water losses. Generally mechanical measures are adopted when the erosion is much severe and simple vegetational control is not sufficient. The main purpose of the mechanical measures for controlling erosion are to increase the time of concentration by intercepting the run-off and thereby providing an opportunity for the infiltration of water, and to divide a long slope into several short ones to as to reduce to velocity of the run-off and thus prevent erosion.

Contour Bunds or Terraces

This practice consists in making a comparatively narrow-based earthen embankment at definite vertical intervals across the slope of the land on a level that is along the contour to impound run-off water behind them so that all the stored water is absorbed gradually into the soil profile for crop use. Contour bunding is generally recommended for low rainfall areas (600 mm) and for permeable soils up to slopes of about 6% in agricultural lands. Contour bunds are also called as level terraces or contour terraces or absorptive terraces. Contour bunds constructed in high-rainfall areas or in areas with impermeable or clayey soil (balck soils) are also called as drainage or channel or diversion or graded terraces or graded bunds. Graded bunds are constructed on a slightly grade (gradually deviation away from the contour) so that the runoff water is easily drained out laterally without causing any erosion.

Surplusing arrangements for contour bunds is of great importance (Rama Rao, 1962) even in scarcity areas (regions of less than 500 mm rainfall) since high intensities of rainfall may cause high runoff results in over saturation and damage on the upstream of the bunds and to some extent on the

downstream side too. The types of arrangement for surplus runoff disposal (Waste weirs) like clear overfall stone weir, channel weir, cut outlet, ramp-cum-waste weir or grass outlet, and pipe outlet are found suitable for contour bunding schemes.

Field bunds

Segmentation of land in between contour bunds into relatively levelled suitable operational plot size depends on land holdings to facilitates even distribution of rain water and withheld runoff for longer period *in-situ.*

Submergence bunds

Submergence bunds are constructed in land having relatively permeable soils with 1-3% slope to hold rain water for sufficient duration for recharging the sub-soil layers and ground water and facilitate sedimentation in the water-spread area. Water is stored during kharif and then allow to flow to the lower ridges to facilitate *rabi* cultivation.

Gully plugging

Gully plugs are earthen embankments usually constructed for blocking the active and erosion - prone gullies for their stabilisation through encouraging vegetation in gully bed and reducing silt load going to the down stream.

Check dams or stop dams

The runoff water or rain water collected and suitably stored in the *nallahs,* small streams and natural drainage outlet, constructing check dams by earthen walls or brick and concrete structures (with check dams) facilitate supplemental irrigations during *kharif* and *rabi* seasons.

Diversion drains

These are used to divert the runoff from above the gully head at a distance of 3 times the height and to allow it to flow at a non-erosive velocity to a suitably protected outlet. A diversion is a graded channel or ditch somewhat similar to a graded channel terrace designed to interacept surface runoff and convey (divert) it safely to an outlet or waterway. A permanent filter strip (15 m width) of close growing vegetation is placed above the channel to catch the silt carried in the runoff from the fields above. A diversion drain has comperatively lesser grade as it is laid across the slope whereas the grassed waterways is laid along the slope having higher grade.

Field to field drainage

This is a practice to drain excess water from individual fields to other and ultimately to water course/main drain or *nallah* in a safer and non erosive velocity. Several types of earthen, vegetative, brick and/or conerete structures are adopted.

Farm ponds and dug-out wells

Farm ponds are bodies of water, made either by constructing an embankment across a water course or by excavating a pit or the combination of both, at sites having relatively impervious layers of clay or silty clay, thereby avoid excess seepage.

3.2 In-situ moisture conservation

Water available in the universe is continually circulated through different phases, changing venues from one to another (hydrological cycle) and use of water in any stage of its cycle may be taken as 'water harvesting' in broadest sense. However, in literature, the word 'water harvesting' has been used in a particular sense to mean water collection out of rain with artifical means. Water harvesting can be the only means of survival under extremely water scanty areas and water scarse situations where annual rainfall varies in the order of 100-250 mm. In areas of normal rainfall, water harvesting could supplement the normal water resources in meeting the agricultural demand or other. Whereas, in high rainfall areas water harvesting becomes superfluous and its objective shifts totally from soil moisture conservation to soil erosion control aspects. In this context, *in-situ* moisture conservation can be viewed as a method of water harvesting specially under rainfed water scanty areas with the basic objective of conserving soil moisture for sustainable use.

In-situ moisture conservation methods depends on type of soil cover management. For poorer land and non-crop cover management, vegetative barrier of two rows with staggered planting alongwith shallow trenching or dyking at lesser intervals, depending upon slope per cent found to be effective while for the crop land across the slope cultivation coupled with dead furrows at appropriate intervals offer greater potential. In case of steeper slope, some sort of levelling is essential and safe disposal of run-off needs greater attention for the sake of stability against erosion and land slip. For afforestation a varieties of soil working techniques specially different types of trenching is quite effective. However, strips of vegetation across slope in between (Das, 1993) could enhance

the effectiveness of any other slope management practise meachanically, organically (vegetatively) and hydrologically.

3.3 Agronomic measures

Soil and water conservation agronomic practices on agricultural land is second line of defence, the first being mechanical or engineering measures to arrest soil erosion immediately. The first step in water erosion is splash (detachment of soil particles) resulting from impact of rain drops followed by transportation through run-off water. Soil conservation agronomic practices help reduce impact of raindrops through interception and thus reduce splash erosion. These practices also help increase infiltration rates and thereby reduce run-off. Reduction in run-off and soil losses is achieved through land meanagement practices (density and kind of crop cover, root growth, water-use by the growing plants and amount of prior crop residues in the plough layer) and associated agronomic practices such as mulching, crop residue management, soil fertility management (addition of organic mannures, green manure and fertilizers), irrigation etc.

4 Soil and Water loss studies

4.1 Runoff control

India receives about 370 million hectare meter (Mham) of precipitation annually, out of which 120 M ha m (33%) is lost as runoff through surface flow to rivers. Critical analysis of runoff and soil loss data reported by various workers (Gupta *et al* 1963, Chinnamani *et al.* 1965, Vasudeviah *et al.* 1965, Singh *et al* 1967, Verma *et al* 1968, Tejwani *et al* 1975, Narayana 1993, and Hazra *et al* 1996) from different locations through out the country revealed that cultivated fallow soil (silty clay loam) with 8% slope and 1250 mm rainfall subjected to very high degree of runoff (35-40% of rainfall) as compared to cultivated fallow soil (clay loam) with 0.5-1% slope and 660 mm rainfall (16-22% of rainfall). Soil under natural cover of various locations recorded consistent very low value of runoff (2-9% of rainfall) irrespective of slope, soil texture and rainfall. Bare soils recorded higher runoff value (70-75% rainfall).

Vertisols (black soil) and *Alfisols* (red soil) are the most abundant soil in the semi-arid tropics. Although they may occur in close association, their management requirements and runoff acharacteristics are completely different (farmers crop alfisols during the rainy season and vertisols mostly during post-rainy season). Miranda *et al* (1993) studied runoff characteristics of these

soils and observed that runoff occur earlier on alfisols and later on vertisols. Their contrasting nature is attributed primarily to difference in types and amount of clay, moisture holding capacity, workability and other associated characteristics. Inspite of the low infiltration rates of vertisols, the water intake rate early in the monsoon is high due to the deep cracks and high water holding cpacity. The cracks continue to exist as such untill sufficient wetting occurs and then the infiltration decreases sharply. In contrast, the initially high infiltration rate of alfisols drops down quickly and often is greatly reduced during the early rainy season by surface sealing caused by the impact of rain drops on the bare soil.

Compaction is normally associated with a decrease in infiltration rate both in alfisols as well as vertisols. However, compaction in vertisols induces the formation of wider and deeper cracks when the soil dry up which subsequently casuses greater intake of water resulting in less runoff.

Rajeswari *et al* (1993) on the basis of laboratory studies concluded that the black soil was found to yield more soil loss alongwith the greater runoff proportions compared to the red soil under both dry and wet antecedent moisture conditions may be due to the higher clay content of black soil (35% and more) than that of red soil (27.5%) which could have caused lower infiltration rates and hence higher runoff leading to increased soil loss. This observation found contradictory to that of earlier observtion (Miranda *et al* 1983) based on field study, simply because of the failure of laboratory conditions in representing the actual field situation.

Both runoff (11.2 - 28.2% of rainfall) and soil loss (4.1 - 28.2 tonnes/ha) increases with the increase in land slope (0.5 - 9.5%) that lead to the reduction in crop yield of what and maize in Doon Valley (Sewa Ram, 1988).

4.2 Soil loss control

Soil loss studies from the country's 20 land resource regions shows that the annual maximum soil losses (64.5 tonnes/ha) occur in the cultivated areas of black soil region followed by the north-eastern region (41 tonnes/ha), ravine region (33 tonnes/ha) and Assam Velly (28 tonnes/ha) with an average value of 16.35 tonnes/ha for the country (Narayanan, 1993).

Critical analysis of runoff and soil loss data reported by various workers (Gupta *et al.* 1963, Chinnamani *et al.* 1965, Vasudiviah *et al.* 1965, Singh *et al* 1967, Verma *et al.* 1968, Tejwani *et al* 1975, Narayanan 1993, and Hazra *et al.* 1996) from different locations through out the country revealed that cultivated

fallow soil (Silty caly loam) with 8% slope and 1250 mm rainfall subjected to very high degree of soil loss (42-44 tonnes/ha) as compared to cultivated fallow soil (clay loam) with 0.5 - 1% slope and 660 mm rainfall (3.5-3.7 tonnes/ha). Soil under natural cover at various locations recorded consistent very low value of soil loss (0.3 - 1.0 tonnes/ha) irrespective of slope, soil texture and rainfall.

Hazra and Singh (1996) reported higher loss in soil from untreated hillocks (41 tonnes/ha) as against untreated cropped land (5.9 tonnes/ha), unprotected natural grassland (16 tonnes/ha) and untreated degraded land (20 tonnes/ha) at Gaharwa watershed (Jhansi).

Reducing the runoff by one half, the soil loss is drastically decreased accordingly to about one sixth (Miranda *et al* 1983).

4.3 Sedimentation control

Topographic and geomorophological characteristics of the watershed greatly influence watershed sediment delivery and hence sediment yield. The fraction of the detached sediment that becomes sediment yield decreases as watershed size increases, whereas the fraction may increase for watersheds with dense channel networks, steep channels, basin slopes and geology that increase run-off volume and/or rates and watershed soils which erode as small sediment sizes (ASCE, 1975; Gregory and Walling, 1973). Erodability may decrease over time with good management practices. conversely, it can increase as progressive erosion removes the surface soil as tillage brings up a more erodible sub-surface soil. Continued intense tillage breaks down soil structure and depletes organic matter, increasing soil erodibility (Wischmeier and Smith, 1965).

Sediment coming into streams, rivers and finally into the sea is the product of watershed degradation processes through deforestation, soil erosion and land degradation. Eroding source areas which generated the potential sediments i.e., eroded soil, earth mass or rock, also yield the chief agent, namely water, which during its flow entrain, transport, deposit and consolidate fragmented materials. On the other hand flow rate and volume of water, either over the land or through channel, are regulated by the catchment charactristics besides the attributes of precipitation, the supplier. The geomorphology and the land uses determine the quantum of potential sediments created in the source area while the hydraulic distance and enroute storages, besides runoff volume and rate determine, finally the portion of eroded materials reaching a particular channel section, reservior or sea (Bali and Jose 1985). The watershed conditions

determining hydrologic reponses as well as sedimentation are convolution of two sets of attributes namely, core (or inherent) and state or temporarily attained with short time changes. These two together at a given place and time regulate the characteristics of flow in terms of quantum, speed, energy and flow vs. time distribution.

Evaluation of Wusheh (Taiwan) integrated Watershed management programme persisted for last forty years (1950-1990) spread over an area of 20480 ha with an average slope of 57 per cent and annual rinfall 2235 mm, characterized by coarse soil texture and weak parent material, yielded 2.2 million m^3 sediment indicated that the annual sedimentation rate was reduced by 45 per cent (1.22 million m^3) per m^3 sediment or Rs. 450 per ha (US $ 0.20 per m^3 sediment), not only help in protecting heavy investment made in the reservoir (for power generation) but also improving inseparable inhabitants' living standard (Sheng, 1990).

Results of different watershed management in Chambal catchment area (Singh and Singh, 1987) indicated that afforestation and mechanical measures reduced both surface runoff (41.7 to 65%) and sediment yield (22-94.3%).

Soil and moisture conservation measures alongwith afforestation of barren hillocks at Gaharwa (Jhansi) watershed reduced the depth of sedimentation from 0.28-0.45 metre (initial) to 0.05-0.10 metre after two crop seasons (Hazra and Singh, 1994) which subsequently reduced further after third crop season (0.01 metre) as a result of quick recovery of vegetation on hill slopes and land adjoining the foothills due to the improvement of surface and groundwater regime of the watershed (Hazra *et al* 1996). Similar observation was recorded at Kharaiya nala (Jhansi) watershed too (Hazra, 1996b).

4.4 Runoff and Soil loss control in relation to vegetational and mechanical treatment

Soil loss is governed by the extent of amount of exposed land surface. It has been reported that a bare fallow plot lost 126 tonnes/ha annually as compared to 1 tonne/ha annually when covered by a double layer of fine mess wire gauge (Hudson, 1971).

Contour farming or cultivation remains to be the single most effective non-monetary input in runoff and soil loss control. Simply by changing the direction of the cultural operations from along the slope to across the slope, i.e, by keeping the on contour or nearly so, the contour furrows so created would

from a multitude of mini barriers across the flow path of runoff which imporves vastly the detention storage *in-situ.* This will in turn increase the opportunity time, and, hence, the infiltration of rain-water into the soil profile where by the quantity and velocity of runoff and its erosine potential are greatly reduced. Maximum effectiveness of contour cultivation is on medium slopes and on deep permeable soils which are either not prone to surface sealing effect or are protected with suitable cover to protect surface sealing. The relative effectiveness of contour cultivation decreases as the land slopes become very flat (less than 2%) very steep (more than 7%) and found to be most effective (Smith and Wischmeier, 1962) on the moderate slopes of 2-7%.

In Doon valley, placing land under agricultural production after deforestation increased the peak rate and volume of runoff by 15%, however, when this watershed was treated with contour/field bunds, the peak rate of runoff was reduced by 86% and volume was reduced by 62% (Sastry *et al,* 1981).

Inter-terrace land treatments like ridge and furrow in case of maize cultivation at Chandigarh resulted in reduction of runoff and soil loss to the level of 4.6 per cent of rainfall and 0.6 tonnes/ha respectively with increase in maize yield by 59.4 per cent over sowing alongwith slope (Mittal *et al* 1985). Treatment of contour trenching, check dams and debris basins alongwith plantation of *Acacia* and *Dalbergia,* in watershed at Chandigarh having 9 per cent slope, resulted in reduction of runoff from 23.5 to 7.0 per cent and soil loss from 80 t/ha to 6 t/ha within 5 years (Mishra *et al.* 1986).

At Agra, a micro wateshed of 0.2 ha yielding a runoff of 23 per cent of rainfall and soil loss of 6.6 t/ha was treated with contour trenching and in the very next year, the watershed yielded negligible runoff and soil loss, however, after 13 years, when trenches were again removed, the run off and soil loss consequently began to increase (run off 14.6% of rainfall and soil loss 4.3 t/ha) thus confirming the effectiveness of contour trenches in the ravines (Singh, 1990).

At Jhansi, Kharaiya Nala watershed covering an area of 5395 ha was treated with soil and water conservation measures like contour bunding, field bunding, gully plugging, field to field drainage outlet, diversion channels (serve as cattle proof trench too), stone walling, staggered contour trenches, continuous contour ridges with bolders and pebbles alongwith vegetational support on contour lines, besides afforestation and silvipasture at suitable places, reduced runoff (as % rainfall) from 70 to 22 (hillocks), 48 to 16 (wasteland), and 30 to 23 (arable land) and soil loss (tonnes/ha) from 41 to 1.9 (hillocks), 20.5 to 0.9

(degraded wastelands) and 5.9 to 2.2 (arable land) after 3 years of watershed management (Hazra, 1996b; Hazra *et al* 1996). Similar observations was also made at Gaharawa watershed (Hazra and Singh, 1992; Hazra and singh, 1994; Hazra *et al* 1996).

Contour and graded bunds reduced soil erosion and runoff significantly and thus improve soil moisture and the crop yield (Krishnaswamy 1987, Rao 1987, Singh 1988).

4.5 Fertility management for the control of soil and water loss

Studies in relation to effect of fertilization (40 kg N + 17 kg P/ha) on pastures and silvipastures in controlling runoff and soil loss (Hazra, 1995 b) at Gaharawa watershed (Jhansi) revealed that application of fertilizer (for 3 years) significatly retarded the runoff by 11 to 21 per cent (Natural rangeland by 14 per cent, improved pasture by 21% and silvipasture by 11%) and soil loss by 25 to 33 per cent (Natural rangeland by 30%, Improved pasture by 25% and Silvipasture 33%) as compared to con trol (without fertilisation) through better protection of soil surface due to enhance foliage and root growth, as well as, improvement in soil physical conditions, specially soil structure, as evident from the increase in soil organic carbon content (0.08 to 0.17%) due to fertilization against non-fertilized control.

5 Hydrological studies

5.1 Watershed management for alternation of hydrological changes

Annual monsoon rains provide us with one of the world's largest source of fresh water, yet the crop failure occurs because of frequent dry spells and throusand of our villages are still without drinking water. One of the important reasons for this is, of course, unequal geographical distribution of our water resources. It is also because of large volume of rain water simply going waste (45% runs off into the rivers and seas and 18% evaporates). "Watershed" being a physical hydrological unit in which water from all over the area flows under gravity to a common drainage channel, and "water" being the single most important variable input, the success of a watershed development plan is centered around the best utilization of water resources of the watershed. Therefore, hydrologically it is essential to evaluate the effect of soil and water conservation measures on reduction of runoff and soil loss, as well as to establish rainfall - runoff relationship for different land uses.

Study conducted at Ootacamund (Jayakumar *et al* 1983) in agricultural watershed indicated that the land treatment (inward terracing) accenuated the peak rate of runoff from 350 l/sec/100 ha to 35 l/sec/100 ha, comparable with that of forest watershed (85 l/sec/100 ha), and watershed lag time increased from 1.21 hour to 3.10 hour, thereby increasing the watershed detention storage.

Imposing field bunding, a 7 per cent increase in recession time, as compared to before treatment, has been increased the opportunity for infiltration/groundwater reacharge, facilitating more than 50% of the watershed area cultivated for crop such as transplanted paddy and sugarcane, besides reducing soil loss from 2.4 tonnes/ha to 0.2 tonnes/ha (94% reduction) and water losses by 67% in Doon valley (Narayana, 1993).

Rain water absorption through infiltration in a forest watershed is twice that of the value for the agricultural watershed (Dhruva Narayana and Sastry, 1983).

5.2 Surface and sub-surface water potential changes due to soil and water conservation measures

Water can be stored either on the surface, in tanks and reservoirs, or below the ground as soil moisture and groundwater. Small reservoirs or tanks (greater in number and less in capacity) throughout the watershed (one in each mini-watershed) will reduce the cost of storage of water much less, benefits large number of people, and promote the recharge of groundwater through percolation (Vohara, 1987).

Medium and deep vertisols of Bundelkhand region (U.P. and M.P.) are characterized by waterlogging, poor drainage, and received bulk of the rains (90% of 1000 mm average annual precipitation) during monsoon, besides having frequent dry spells both during kharif and rabi seasons, capable of generating 30 to 60 percent of runoff, provide ample scope for water harvesting through soil and moisture conservation practices (Hazra, 1988; Pal, 1996) to facilitate surface as well as sub-surface storage of water for its recycling at critical stages during *kharif* (under condition of early withdrawal of monsoon) and succeeding *rabi* crops.

Several watershed management studies clearly shown that water harvesting devices like check dams, ponds, small contour ditches, gully plugs etc helped in impounding 25 to 50% runoff for multipurpose use, besides rise in water table depth from to 12 m. Impounded water successfully mitigate irrigation

requirement of *kharif* as well as rabi crops, (increased substantially stored water potential of watersheds, cropping intensity, crop yield and brought majority of the watershed area under irrigation (Hazra and Singh 1994; Grewal 1995; Hazra 1996; Maskina *et al* 1996).

5.3 Irrigation water resource development through surface water detention/ storage

The water utilization (harvesting of excess runoff of 6 ha watershed area) studies of dug out pond (having the water spread area of 1.3 ha, depth 3 m, and storage capacity of 2.2 ha m) at Bhopal, Nimje and Bhandarkar (1990) showed that loss of water through evaporation and seepage varied from 38 to 68% of stored water depending on storage time of 3.5 to 6.5 months. Water utilized in *kharif* irrigation for transplanting of rice was refilled (8 to 36% of stored water) depending on rains. Water utilized from dug out pond was 69 per cent of the stored water. Area irrigated during *kharif* and *rabi* found to be 1.5 and 6.5 ha, respectively. It was observed that if one irrigation in October was given through dug out pond, at 9 cm depth, four times the area of watershed (6 ha) could be covered with the stored water. if two irrigations were given in October and November, one and half times the watershed area could be covered and for three irrigations in October, November and December, only two-third of the watershed area could be commanded.

5.4 Irrigation water resource development through sub-surface recharge and exploitation

Rise in water table from 5m to 12m, noticed at different watersheds, due to soil and moisture conservation treatments, clearly points towards the fact that significant increase in sub-surface water storage potential, not only recharged ground water sufficiently, but opened up avenues for irrigation, during moisture stressed period at critical stages of crop growth, specially in *rabi*. This stored water also made possible to raise summer crops (specially vegetables) which could not perhaps even imagined before, as evident from the substantial increase in the number of dug out wells (10 to 40 times) in the watershed (Hazra and Singh 1994; Grewal 1995; Hazra 1996a; Suraj Bhan, 1996, Hazra *et al* 1996b).

6 Crops and Crop management

6.1 Management of crops under rainfed agriculture

Water is the key component in rainfed farming and therefore, all principles behind rainfed farming centre around efficient management of

rain-water, which means utilization of rain-water to its fullest possible extent through scientifically sound crop, soil, runoff and slope management based on ecologically sound farming practices.

The objective of crop management is to establish quick and an effective ground cover soon after the onset of rains. A good ground cover is achieved through early planting, ensuring adequate stand through using viable and good quality seed at recommended rate, and adopting soil-conserving crop rotations including multiple cropping, strip cropping and agroforestry. Agroforestry, growing food crop annuals or raising livestock in association with trees or woody shrubs and perennials, is another viable option that provides the needed ecological diversity for minimizing runoff and soil erosion (Lal, 1989; McDickan and Vergara, 1990). Ensuring balanced availability of essential plant nutrient through judicious use of chemical fertilizers and organic amendments is essential for obtaining a vigorous crop growth. Adequate control of pests (weed, insects and pathogens) is also essential for obtaining a vigorous crop growth. Farms with poor crop growth are more prone to erosion and least efficient in rain-water harvesting than those with a vigorous growth (good farming). The magnitude of soil erosion does not depend as much on 'what' crop is grown as it does on 'how' it is grown. Soil enhancing practices (system of soil surface management that enhance and maintain favorable structural condition) include mulch farming, conservation tillage methods (Lal, 1989), rough seedbed, countour tillage, ridge-furrow systems and tied-ridges (Lal, 1990). Suitability of different soil management techniques depends on ecological conditions. Techniques involving ridge-furrow system, tied-ridges and rough seedbed are suitable for semi-arid and arid regions; whereas, no-till or reduced tillage systems are applicable for humid and sub-humid region. Farming system based on mulch farming and vegetative cover reduce runoff rate, amount, and its velocity. In addition to increasing resistance to flow, plant roots anchor the soil and increase its resistance against shearing force of running water.

Optimum plant population not only minimise risk involved in rainfed farming (weather aberration due to either failure of most expected rains or late onset of rains) but helps in obtaining satisfactory yield. It has been observed by Rao *et al* (1990) that in case of sorghum, thinning to 50% found to be optimum, recording 2150 and 1208 kg/ha yield under moderate and severe moisture stress conditions respectively, which correspond to 40 and 120 per cent increase in yield over control (no thinning) respectively.

6.2 Crops and varieties

Essential ingredients of successful crop production under rainfed situation includes use of short duration and high yielding crop varieties having better moisture use efficiency, good vegetative canopy cover and their suitability for double cropping and intercropping. Introduction of leguminous crops having high leaf canopy (Soybean, etc.) during *kharif* season not only minimised soil and runoff loss but also enriched soils in nitrogen content and water holding capacity (Tyagi and Singh, 1990; Hazra, 1988; Pal, 1996). In *rabi* season, selection and cultivation of deep rooted crops like linseed is most promising and useful on rainfed lands where soils remain moisture deficient throughout the growing season. Lentil, a *rabi* pulse crop, which can grow well in moisture stress conditions could be another choice for rainfed situation.

6.3 Intercropping studies

Growing of single or few rows of erosion resisting and erosion-permitting crops in alternate rows (mixed or intercropping) or strips (Strip cropping) on contour or across the slope with the objective of breaking up long slopes and preventing erosion and soil loss having advantages of good crop cover, feeding of crops from different soil layers and under rainfed conditions an assurance against a total failure.

In medium black soil, a mixed crop of wheat+gram gave consistently higher yields than pure crops. Similarly, in the alluvial soils of Agra, mixed cropping of pearl millet + pigeon pea was found to be an economic practice under rainfed conditions (Narayana, 1993). At Kota, 1:1 inter-cropping sorghum+pigeon pea was found more economical that pure sorghum or pure pigeon pea (Singhal *et al.* 1977). Raising of sorghum+pigeon pea reduced runoff, soil loss and nutrient losses and at the same time economized nitrogen application to the extent of 25-30 kg N/ha (Narain *et al* 1980). Further, studies have revealed that 1:1 ratio of pigeon pea + sorghum, pigeon pea + black gram, and pigeon pea + green gram sown at 30 cm distance, performed consistently better than 1:2 or 1:3 ratio of these crops (Narayana, 1993). Intercropping or strip cropping with legumes and cereals has been found to reduce runoff and soil losses. Studies on intercropping of cowpea with maize at Deharadun (Bonde and Mohan, 1983) have revealed that after 50 days of sowing, canopy cover under pure crop of maize is 69 per cent while that under double row intercrop of cowpea it is 93 per cent. Correspondingly splash under pure crop of maize is 60 g/57.6 m^2 as against 22g/57.6 m^2 under intercropping.

Intercropping of cowpea (double row) for vegetable purpose is more advantageous than intercropping of cowpea (double row) and maize for grain yield both in terms of monetary benefit and soil conservation.

The sorghum based intercropping is found to be more remunerative and efficient in Bundelkhand region (Hazra, 1988). The sorghum+pigeonpea in 1:1 ratio gave net return of Rs. 2643 per ha as compared to pure sorghum of Rs. 1652 per ha. Intercropping of maize with cowpea (1:2) provide better soil cover (93% canopy on 50 DAS) in comparison to pure maze (69% canopy on 50 DAS).

6.4 Sequential cropping / Crop rotations

Crop rotation involves incorporation of legumes with cereals in a sequence to take advantage of different feeding zones, both for nutrient and water, and to offset disadvantage of monocropping in controlling pests, thus result in better soil coverage, which helps in efficient soil and water conservation. Results at Dehradun have shown that net return from mize-pea rotation was Rs. 1622/ha as compared to maize-fallow (Rs. 988/ha) or maize-wheat (Rs. 1079/ha). At Agra, pearl millet + pigeon pea - mustard sequence was found to be the most profitable in the reclaimed ravine lands. Bajra-Cowpea was the next best rotation. Crop rotations involving *kharif* pulses (greengram, blackgram, cowpea, soybean) and oilseed crops (mustard, safflower) gave maximum returns (Subhas chandra, 1983; Agnihotri and Bhusan, 1982; Srivastava *et al.,* 1980).

Cowpea as intercrop not only helps in increasing the yield of base crops but it also gives additional yield of cowpea (green pods) resulting in more profit. It also protects the soil from beating action of rains and is therefore, recommended for the region growing cotton, pigeonpea and castor (Sharma, 1980).

Rainfed farming at Bhopal, indicates that the most responsive cropping sequence to supplemental irrigation found to be soybean-chickpea followed by soybean-wheat (Nimje and Bhandarkar, 1990).

6.5 Tillage practices

Land preparation including post-harvest cultivation and preparatory tillage influence intake rate of water, obstruction to surface flow and consequently the rate of erosion. Deep ploughing or chiselling of fields after crop harvest have been found to increase infiltration rates of field. Bhusan *et al.* (1977) reported a significant residual effect of deep tillage on the yield of toria crop and maize. Moisture extraction pattern proves the efficacy of deep tillage in conserving moisture in profile and makes it available to the plant roots, thereby increasing the

moisture use efficiency for increased production of maize as well as toria. Similar observations were recorded in case of pearl millet at Agra by Singh and Verma (1994). Summer ploughing with disc plough increased yield of seed cotton by 4.3 q/ha over no summer ploughing (Suraj Bhan, 1996). tillage with mould-board plough increased total grain production of maize and wheat (6.6 q/ha) as compared to shallow tillage (5.9 q/ha). For maize-wheat cropping, deep ploughing should be given to maize and surface mulching should be applied at the fag end of the monsoon season (Bhusan and Ghosh, 1981).

Studies on *Alfisoils* under semi-arid tropics by Yule *et al* (1990), indicate that productivity in this soil is limited by high runoff, high erosion and poor crop establishment and growth. Surface sealing, argillic B horizons and cemented murrum (fragmented rocks) layers are hydroclic throttles in the profile. Normal tillage increase infiltration by breaking the surface crust and deep tillage and sub-soiling may break the top of the B horizon. However, tillage tends to decrease soil organic matter and soil structural stability therefore, increasing surface crusting. Awadhwal and Smith (1990) found that bulk density and penetration resistance reverted to pre-tillage values within a crop season while deep tillage effects could last for 2 to 5 years (Pathak *et al.* 1985). Tillage may also increase hardsetting due to the decrease in organic matter and soil structure disturbance, thereby making tillage more difficult. Therefore, soil management that includes a reduction in the amount of tillage would be beneficial.

Studies on vertisols under semi-arid tropics by Sharma and Gupta (1990) indicates that shallow tillage in between cropped rows delayed the appearance and development of shrinkage cracks, reduced evaporation and conserved about 4 cm of water in the soil profile. This enhanced the rainfed wheat and safflower yields by about 12 and 22 percent respectively. Shallow tillage 3-4 times in standing rainfed chickpea, linseed, wheat and safflower crops led to increase in seed yield by 22.3, 6.9, 6.1 and 10.6 per cent, respectively, and enhanced water use efficiency by 24.6, 10.2, 24.2 and 19.4 per cent, respectively as compared with respective untreated crops.

6.6 Fertilizer use

The effect of fertilizer by improving vegetative growth of crop (crops canopy) and thereby reducing soil erosion is distinct. Organic manures and green manures not only supply plant nutrients like fertilizers, but help in improving soil physical conditions and simultaneously improve rate of infiltration and soil structure thereby affecting soil erosion process. Application of FYM at Bellary

(Karnataka) @ 2-6 tonnes/ha neither improved the yield of rainfed cotton or sorghum non influenced dispersion ratio of soil (Narayana, 1993). Unlike FYM, green manuring is more important in view. of improvement in soil physical conditions as decomposition occurs *in - situ.* In a study at Dehradun (Narain *et al.,* 1984), sunnhemp green manuring reduced peak rates and volume of runoff, soil and nutrient losses. It improves soil fertility and stored most soil moisture for second crop of wheat as compared to natural fallow. Hence, the yield of rainfed wheat was improved by about 25 per cent.

Depending on availability of soil moisture, application of fertilizers has got distinct effect on vegetative growth and also influence the yield. In the process, crop canopy has remarkable effect on run off and soil loss. The addition of root mass is also proportional to vegetative growth of a crop. A good crop is likely to leave more root mass, and therefore, has beneficial effect on soil physical conditions.

Application of N upto 120 kg/ha in pearl millet, increased daily and seasonal consumptive use, water-use efficiency, rainfall-use efficiency, dry matter accumulation and soil moisture extraction percentage from deeper layers (Singh and Verma, 1994).

Integrated watershed management results in increase in water resources, its efficient utilization and awareness among the farmers contributed positively that drastically increased the fertilizer consumption, particularly urea (10 to 45 tonnes), DAP (5 to 30 tonnes) and $ZnSO_4$ (0 to 1.5 tonnes) in different watershed at Arawalis (Sharma *et al.* 1995).

6.7 Mulching

Mulching is an essential component of sustainable, productive rainfed cropping system. Surface mulching by spreading crop residues or any organic residue or suitable inorganic material on bare land surface or inter-row space in line sown crops, is employed to minimise splash and influence of rain drops on bare surface, to reduce evaporation, to control weeds, to reduce excessive heating of surface soil so that microbiological activities are not adversely affected and physico-chemical properties of soil are improved which ultimately result in increased yield of crops.

In case of *Vertisols* (black soil), application of crop residues (safflower residue, sorghum cob-husk, wheat straw, soybean residue) as surface mulch at

the rate of 5-6 tonnes/ha suppressed the evaporation losses and led to increases the water use efficiency of a number of crops by 12 to 45 per cent with corresponding yield advantages of 15 to 28 per cent depending upon seasonal variations. Plastic mulching for 2 weeks prior to planting of wheat tended to reduce moisture gradients in the profile and caused resetting of upper drier soil layers (increased soil moisture from 31 to 39% in top 10 cm soil layer) resulting in early establishment of wheat seedlings, 36 per cent more consumptive use of moisture and 10 per cent additional yield as compared with unmulched plot (Sharma and Gupta, 1990).

Straw mulch on *Alfisols* (red soil) increased annual infiltration by 127 mm on an average and tillage by 26 mm and these effects were not cumulative. Zero till straw plots had 101 mm more annual infiltration than 20 cm tilled bare plots, an equivalent management 15 farmer practice. There is evidence of accumulating benefits from straw mulch over the years (Yule *et al.* 1990).

Application of mulch for better water conservation and yield increment has been advocated by several workers (Singh *et al.,* 1967; Dakshinamurti, 1972; Singh and Sinha, 1977; Singh and Bhusan, 1978; Sachan and Bhan, 1986; Hazra, 1988). A dose of 2 tonnes/ha gave 18 per cent rainfall as run off and 72 tonnes/ha of soil loss whereas mulch @ 4 tonnes/ha gave 15 per cent rainfall as run off and 5.4 tonnes/ha soil loss as compared to 37 per cent of rainfall as runoff and 17.7 tonnes/ha of soil loss when maize was grown without mulch (Khybri, 1983), indicates mulching even @ 2 tonnes/ha can bring down soil erosion to permissible limit besides reduction in the cost of muching. However, dust mulch of 5 cm appears to be the most practical way of soil moisture conservation as it produced 22 per cent more yield than control (Singh and Bhusan, 1978). Increasing the depth of dust mulching to 10 cm reduced the benefits compared to 5 cm dust mulch, which could be due to exposure of moist surface to evaporation (Rao and Chittaranjan, 1983).

6.8 Supplemental irrigation

The potentiality of harvested water as a source of supplemental irrigation was enormous, particularly during dry years. During acute drought period, application of small amount of water not only saves the crops from virtual drying but also helps in assured production. Application of irrigation (2.5 cm) during drought year in Bundelkhand, improved yields of sorghum by 15 per cent, maize by 11 per cent, pigeonpea by 28 per cent and sunflower by 43 per cent over no such application in the respective crops (Hazra, 1988).

In Dehradun (Singh, 1990) 82-89 per cent increased yield of wheat was recorded by applying one irrigation (5 cm) either as presowing or at crown root initiation (CRI) stage and 128 per cent increase in yield by giving two irrigations (5 cm each), one as presowing irrigation and another at CRI stage as compared to control. The study carried out with barley revealed that presowing irrigation (5 cm) gives 32 per cent increase in yield over control. Similarly, two irrigations (5 cm at presowing and 5 cm at flowering stage) gives 36 per cent increase in yield over control in case gram.

Highest BC ratio of 3.4 was observed when supplemental irrigation (5 cm) was provided for sorghum and was only 1.1 in case of safflower with 4 as well as 6 and 8 cm of irrigation (Chittaranjan *et al* 1981). In case of red soils also, the response of crops to supplemental irrigation was very high (Rao *et al*, 1981).

In Bhopal (Nimje and Bhandarkar, 1990), a supplemental irrigation to rice crop at transplating increased the yield by 44 per cent and two irrigations at transplating and grain filling stage raised the yield levels by 90 per cent over no irrigation. Soybean also responded significantly to irrigation (8 cm) at grain filling stage in the years of early withdrawal of monsoon and an increase in grain yield of 42 per cent over control was recorded. Supplementary irrigation (8 cm) at pre-sowing to chickpea, linseed and safflower crops, resulted in 64, 17 and 37 per cent increase in grain yield, respectively over no irrigation. Another irrigation at CRI in wheat, at pod formation in chickpea linseed and safflower gave an increased grain yield of 78, 90, 56 and 51 per cent, respectively over no irrigation.

The results of application of 5 cm of water to different cereal, pulse, oilseed and cash crops under various agroclimatic conditions showed considerable increase in crop yields with high (20 kg/ha/mm) water-use efficiency (Singh, 1983).

One pre-sowing irrigation of 50 to 75 mm and one irrigation of 75 mm at crown root initiation stage was found sufficient to get wheat yield of about 35 q/ha (Grewal and Juneja, 1986). For higher productivity, it is better to spread the water over larger area if available rather than giving more than two irrigation in a limited area (Grewal *et al.*, 1989).

6.9 Soil crusting

Rainfed crops of dryland areas are often subjected to soil crusting if rain occurs after sowing of seeds. The severity of soil crusting is more in case of rains received after sowing and before emergence followed by dry spells. The seedling

emergence depends upon crust strength at the time of emergence of seedlings (Parihar and Agarwal, 1975). Amongst the forage crops, pearl millet was found to be most sensitive to soil crusting followed by maize. Cowpea yields were not much influenced by soil crust strength upto 3 kg/cm^2. Application of dry grass mulch, pearl millet stalk mulch and FYM @ 10 tonnes/ha reduced the crust strength to 1/3rd and almost increased seedling emergence by three times and increased forage yield of pearl millet by 95 to 265 per cent over control yield (Hazra, 1986).

Studies on drying pattern of red laterite loam soil (Wadood and Mohsin, 1987) indicated that initial high and constant rate of evaporation results into the formation of a hard layer on surface soil (soil crusting) which in turn, impedes the moisture loss from the soil and slower down the upward movement of water from lower layers. Thus soil crusting in red light-textured soil *(Alfisols)* may be considered as natural mulch (Pal, 1996).

7 Water resource development influencing crop productivity

7.1 Change in cropping pattern, intensity and crop productivity with increased water resources

Efficient rainfed water use is a key to stabilise production at higher level from rainfed area, which occupy 72 per cent of the total arable lands. Improved soil and water conservation measures alongwith suitable crop production technology is essential for using the meagre rainfall *in - situ* or where it is in plenty to harvest the runoff and recycle it to the cropped area when it is critically required to maximise production per unit area and per unit water through multiple cropping having double cropping in the area which are otherwise conventionally monocropped. Results of watershed management project in Ambala district have indicated that 2-3 fold increase in yield and stability in agricultural production can be achieved with the adoption of water harvesting and its recycling.

Studies in Shiwalik region (Chandigrah) indicated that application of 5 cm irrigation (presowing) increased yield (kg/ha) of wheat (1303 to 3064), gram (837 to 1026), mustard (344 to 502) and Taramira (655 to 1021). Second irrigation of 5 cm (CRI or tillering stage) increased yield further to the tune of 4077, 1200, 688 and 1198 kg/ha respectively (Singh *et al.* 1987, Sud *et al.* 1988). The maximum water use efficiency of 61 kg/ha - cm was, however, obtained with one irrigation of 5 cm. One supplemental irrigation (5 cm) at critical stage increased yield of wheat (50% at Agra, 100% at Ludhiana, 300% at Rewa) Sorghum (50% at

Bijapur, 72% at Maharastra, 100% at Sholapur, 300% at Bellary) Tomato (127%) ragi (57%) and chillies (113%) at various locations.

Results of Kharaiya Nala(Jhansi) watershed covering an area of 5395 hectares (Hazra 1996 c) revealed that 78 hectare-meter impounding water, through check dams and gully plugs, increased irrigational potential from 9.6 per cent to 69 per cent of the cultivated area corresponding to the increase in cropping intensity from 81 per cent to 172 per cent. Ensured irrigation through water harvesting facilitated introduction of groundnut (50% Kharif area) and Soybean (7% Kharif area) which in turn caused 80 per cent reduction in area under sorghum+pigeon pea, and bring more area under *rabi* cultivation (double cropping). Area under wheat, gram and tomato were increased by 3.6, 3 and 25 times respectively. Over all crop productivity increased from 0.7 to 2.8 tonnes/ha (0.6 to 1.7 t/ha in *kharif,* 0.8 to 3.2 t/ha in *rabi,* and 0 to 14 t/ha in *zaid* (summer) vegetables).

Musiguda (Phulbani, Orissa) watershed covering an area of 848 ha having average annual rainfall 1200 mm, prone to intensive soil erosion (105 tonnes/ha/year) and inhibited by tribal people, undergone vast change in crop production and socio-economic conditions through watershed management programme (Bhol *et al* 1990). Impound water (54117 m^3) helped to introduce suitable intercropping like maize+cowpea, pigeon pea + ground nut, besides being increased the productivity of the traditionally grown crops like maize, ragi, black gram, green gram, mustard and ground nut by 132, 50, 40, 35, 78 and 70% respectively. Mustard preferred to be grown in rabi after kharif crops like maize, cowpea, green gram and black gram.

At Padalsingi (Maharastra) watershed project, soil and water conservation practices lead to the increase in irrigated area from 2 to 100 ha, summer cropped area from 0.8 to 40 ha, doubled the productivity of food grain crops (from 5q/ha to 10 q/ha) with an increase in cropping intensity from 106 to 151 per cent (Phadnawis, 1990). Bajra + pigeon pea remained the most favoured cropping system followed by greengram, groundnut, and bajra (during kharif), Sorghum, wheat and gram (during rabi), and sugarcane, sunflower (during summer).

At Rendhar (Jalaun, U.P.) Watershed adoption of soil and water conservation measures (for 8 years) lead to the increase in irrigated area from 56 to 690 ha, cropping intensity from 100 to 184 per cent, crop productivity of cereals (6.3 to 33.7 q/ha), pulses (6.8 to 24.4 q/ha) and oilseeds (2.5 to 23.5

q/ha) through exploitation of impounded surface water (180000 m^3) as well as underground water resources, and facilitated incorporation of crops like soybean, pea, potato, berseem and sugarcan in cropping system (Suraj Bhan, 1996).

7.2 Influence of soil and water conservation practices on land use pattern, crops and crop productivity

Various soil and water conservation measures alongwith improved agro-techniques at Bajar-Ganiyar (Mohindragarh) and Siha (Rewari) watersheds (Sharma *et al.* 1995) brought a drastic increase in the crop production of almost all the crops in irrigated as well as rainfed areas. The per cent yield increase recorded was to the extent of 40-43 per cent in Wheat, 20-28 per cent in rainfed mustard, 45-94 per cent in irrigated mustard, 107-156 per cent in rainfed barley, 91-298 per cent in irrigated gram. Comparative study of suitability of crops have revealed that mustard is a better choice than wheat under limited irrigation condition because of an average mustard yield of 18-21 q/ha (with 1 or 2 irrigations) which is equivalent (in monetary terms) to 40-45 q/ha wheat yield which needs 5-7 irrigations. Thinning of mustard crop within 3-4 weeks after sowing to get a plant population of 2 to 2.5 lakhs/ha has been reported beneficial (25% increase in yield).

Considerable increase in food grain production in Sukhomajri village has been reported (Grewal, 1995) due to integrated watershed management also. The total food grain production increased from 450 to 1850 q/year between 1975 (before) and 1988 (after) the project. Since animal husbandry is the main concern of the Shiwalik farmers (Sukhomajri watershed), continuous supply of fodder remains was the major concern. The farmers tend to put more area under barseem (Egyptian clover) at the cost of other crops though barseem requires more frequent irrigation. Some farmers even tend to growing rice unmindful of limited supplies of water. There is one advantage in integrated watershed management system that immediately after the monsoon rains, the quantum of water available becomes known. The planting for *rabi* crops shall have to be based upon this availability which may vary from year to year. If the winter rains are good the irrigation need for *rabi* crops are low,and in such condition fodders like bajra, pulses like summer moong and vegetable like okra could be taken to utilise the surplus water, so that the stored water in reservoirs could be utilised for creating storage for the next year's runoff.

As a result of integrated watershed management at Jhansi (Hazra *et al.* 1996), the area under *kharif* and *rabi* increased by 85 and 233 per cent,

respectively. The area under summer crops, formerly nil, subsequently rose to 146 ha i.e., 4 per cent of the cultivated area. Among the main *kharif* crops, groundnut and soybean, which are new introductions in the area, coverved 49 and 6 percent of the total cultivated area, respectively. However, there was decline (from 29% to 4%) in the area under sorghum + pigeonpea. In the case of *rabi* crops, there was a phenomenal increase in the area under wheat (260%), gram (204%), peas (185%), mustard (40%) and vegetables, specially tomato (2383%). Among the summer crops, vegetables, namely, onion, colocasia, bottle gourd, bitter gourd and ladies finger were grown over 112 ha. All these lead to an increase in the cropping intensity from 81 per cent to 172 per cent. The productivity of crops increased substantially from a very low level of 0.6 to 1.7 tonnes/ha *(kharif)*, 0.8 to 3.2 tonnes/ha *(rabi)*, 0 to 14 tonnes/ha (summer vegetables), 0.4 to 2 tonnes/ha in scree deposits area, leading to an overall increase in crop productivity by 0.7 to 2.8 tonnes/ha, during the period of three years intervention.

8 Pasture development and afforestation as soil and water conservation measures

8.1 Pasture, Silvipasture and Afforestation

The grasses and legumes are considered best vegetational means for soil and water conservation (Hazra, 1996 c). Exploitation of soil at greater slopes (more than 3%) and in shallow soils with poor fertility for crop production does not always seem to be as much profitable as by putting those lands under grasses. These grasses when properly managed, can provide much more profit than arable farming 9particularly in degraded land and mostly help to build up soil fertility for their greater economic exploitation in the future. Grass provides adequate canopy against the action of rain drops. In addition, grasses intercept rain drops through their canopy to the maximum, they also obstruct the easy flow of water in slopes. The mass of the litter and the rhizomes or stolons or runners, all act like speed breakers for the running water on slopes including soil binding characters. Further, these also collect soil particles from the running water. The net result is that the loss of soil from areas put under grasses is reduced to a great extent.

Perennial vegetation, such as trees and grasses are not only the alternatives for economic utilization of degraded lands unsuitable for agriculture but at the same time these successfully prevent soil erosion and runoff by considerably reducing the soil and water losses from such lands usually left

fallow. It has been well established that the perennial vegetation , by effective interception of rain water, reduces the energy of rain drops falling on the soil and, thus, helps in minimizing the soil dispersal and consequently the erratic flow of runoff.

Even the degraded ravines at different locations supported natural regeneration that results in luxuriant growth of many species of forage grasses within 5 years and herbs, shrubs, trees within 10-12 years owing to protection from human and livestock interferences only (Prajapati, 1979; Sharma *et al.* 1981) suggest a good scope for bringing uneconomical marginal lands into profitable land use by the process of natural regeneration and development into woodlands through succession.

Studies in black-soil region of Bellary reveals that *Cenchrus ciliaris* showed encouraging performance to protect contour and field bunds while *Dichanthium annulatum* for protecting the channel of waterways, *Glyricidia maculate* and *Ipomoea carnea* were found to protect the channel *(nalah)* margins. Tree species like *Azadirachta indica, Prosopis cineraria, Leucaena latisiliqua* and *Acacia nilotica* having top feed value proved suitable for planting along the reclaimed *nalah* fringes (Sbbayyan, 1980).

8.2 Soil and water conservation on pasture development

The grasses have tremendous restorative properties specially for the rehabilitation of the degraded soil. It is not only that the grasses once planted on highly eroded and degraded sites continuously reduce the soil and water loss depending upon the growth and canopy coverage but also, as progressively as the time passes, the vegetation itself helps in improving the soil physico-chemical conditions which in turn help to contain further runoff and soil loss. Thus good pasture, firstly reduce the soil and water losses through their soil binding and protecting properties, and secondly, accelerate the process of conservation by improving the soil properties. Any soil properties that adds to the biomass production from grasses and legumes also help in retarding soil and water loss. Nanjundappa (1981) reported that the average soil loss from deforested areas was to the extent of 12-43 tonnes/ha/year in black soil and 4-10 tonnes/ha/year from red soils. The extent of soil loss under various land use system has been reported by Yadav (1986) which clearly indicate that natural vegetation, plantation and natural grasses offer tremendous influence on soil loss. Hazra and Singh (1992, 1994) studied the effect of type of grassland vegetation on run off and soil loss and on some important soil properties observed that simply protection of

natural grassland not only changed the composition of the species constituting grassland vegetation and yield but greatly improved the soil properties like organic matter content and water stable aggregates which ultimately reflected in the reduced runoff and soil loss. Protection of natural grassland from grazing for 3 years, reduced runoff loss from 35 to 18 per cent of annual rainfall and soil loss from 16 to 3.2 t/ha; increased forage yield from 0.9 to 2.2 t/ha and soil organic carbon content from 0.16 to 0.38 per cent.

Similarly, adopting the improved practices for grassland (Soil and water conservation measures along with Silvipasture) in degraded lands and barren hillocks, greatly appreciated the dry forage yield (10 to 48 times), soil organic carbon content (4 times) and water stable aggregates (2 to 3 times) which further resulted in the reduced soil loss (1/20th) and runoff (1/3rd).

8.3 Fertilizer use on pasture production

Application of fertilizer (N @ 40 kg/ha + P @ 17.5 kg/ha) to range grasses had helped in improving herbage yield by 39, 25 and 78 per cent in case of silvipasture, pasture and natural rangeland situation, respectively and reduced runoff by 16-28 per cent and soil loss from 0.2-1.2 t/ha against 36-42 per cent of runoff and 7.8-11.2 t/ha of soil loss in case of natural grassland (Hazra, 1995 a).

Studies on effect of nitrogen fertilization (Hazra, 1995 e) it was observed that moderate level of fertilizer application (20 kg N + 8.75 kg P/ha) increased forage yield by 76 per cent and adequate fertilization (40 kg N + 17.5 kg P/ha) by 145 per cent over no fertilization. Highest nitrogen responses of 97 and 89 kg/kg N was noted with moderate and adequate fertilizer application situations, respectively in case of improved pasture as against 59 and 54 kg/kg N in case of natural vegetation with respective rate of fertilizer applications.

Addition of small amount fertilizer nitrogen (20-40 kg N/ha) helped to a great extent in realising 40-60 per cent higher herbage yield (Hazra and Singh, 1994). Application of non-symbiotic nitrogen fixers like *Azotobacter* or *Azospirillum* together with 20 kg N/ha gave yield equivalent to that from application of 40 kg N/ha. Application of *Azospirillum* increased herbage yield of grasses by 7-23 per cent over no inoculation (Hazra, 1995 b).

8.4 Bio-diversity (species) composition changes and succession changes due to watershed management :

There is a great variation in nature and also biological diversity in choosing grasses and legumes for soil conservation purposes under specific

agro-climatic locations. The nature and growing habits of grasses and legumes togetherwith managemental practices imposed on them greatly influence their efficacy containing soil and water loss. Dense covered legumes are found to be efficient plants in this direction than the grasses. The legumes and the grasses, the foliage of which were dense near the ground and the mean foliage angles with the horizon were more acute provided better ground cover (Hazra, 1995 d). Working at Gaharawa watershed in Jhansi, Hazra and Singh (1994) reported that the grasses like *Cenchrus ciliaris* and *Pennisetum pedicellatum* did also provide good cover and reduce soil loss to 0.52 tonnes/ha and 0.80 tonnes/ha, respectively, as compared to 12.7 tonnes/ha from degraded grasslands. *Dicanthium annulatum* are also good soil binders and help in protection of mechanical conservation structures. Mixing of grass and legumes *(C. ciliaris + Stylosanthes hamata)* and also mixing of two grass species like *(C. ciliaris + P. pedicellatum)* and *(Pannicum maximum + P. pedicellatum)* are also found better than single species in containing soil and water loss.

In case of revegetation programme, some species are required for immediate cover and some are required for permanent cover. The species which can grow on loose, nutritionally poor and rock debris are to be hardy, easy to be propagated, fast growing with good crown and deep root system. To provide an immediate cover, planting of *Pennisetum purpureum* and Hybrid napier are found useful. *Panicum maximum* is also suitable for good and fast coverage (Hazra, 1995 a). After protection of hill slopes, a number of useful grasses including shrubs come up naturally.

8.5 Forage production from bunds, hills, hillocks, plateau and bunds

Modern farming, based on principles of soil conservation and development, provides contour bunds, grassed waterways and plugged gullies, in slopy land for safe utilization, which cover about 10 to 30 per cent of the total area. There is no other better vegetation than grasses for the economic exploitation and development of such areas because grasses having a good rooting pattern and close ground cover serve as good soil stabilizers (Hazra, 1995 c). In a watershed at Jhansi, silvipasture system was adopted with tree species like *Albizia lebbeck, Acacia nilotica, Leucacena leucocephala* etc. alongwith *Cenchrus ciliaris* (grass) and *Stylosanthes hamata* (legume) in about 665 hectares area, mostly degraded hills and hillocks. Appropriate soil and water conservation measures like staggered contour trenches, stone ridging on contour lines, gully plugging etc were adopted and stabilized through silvipasture system. The study revealed that there was tremendous regeneration of natural vegetation

and improvement in soil resources, besides increased in forage productivity from a meagre 0.72 tonnes/ha to 5.86 tonnes/ha in four years (Hazra, 1995 b).

Forage productivity (dry forage) before and after soil and water conservation and afforestation works in barren hills at Gaharawa watershed at Jhansi (84 ha area) indicated that the lowest yield of 2250 kg/ha was observed in hill top against an yield of 5620 kg/ha on hill slopes (mid-hill), 7680 kg/ha from bottom of hills and 9160 kg/ha from plain land, in comparison to the yield of bare hill (untreated) to the tune of 94 (hill top), 220 (hill scope), 530 (bottom hills) and 996 kg/ha (foot hills) or plain land/respectively (Hazra and Singh, 1992, Hazra, 1994).

At Kharaiya Nala (Jhansi) watershed, Hazra *et al* (1996) observed that as a result of project activities (1990-91 to 1993-94) the area which was available for free ranging of the village livestock reduced to almost nil. There was also a substantial reduction in the case of non-arable land, mainly community grazing land and land used for micellaneous purposes. The entire 317 ha of privately owned degraded lands were reclaimed and brought under crop production. However, there was an addition of 132 ha and 12 ha of field bunds and gully plugs respectively, which were assigned to grass production. In spite of reduction in the total area (culturable fallow) available for grazing by 23 per cent, the dry forage production increased by 235 per cent compared to the pre-project phase. The increase in dry forage production is mainly due to reseeding of field bunds and hill slopes with grasses and legumes, and regenerating old root stocks on hill slopes. The average dry forage productivity went up from 0.70 to 5.30 tonnes/ha/year during the post-project phase. Bhusa (wheat straw) production increased by 213 per cent due to increase in total cropped area and cropping intensity. As a result of project intervention, the initial forage deficit of 5899 tonnes/year, was not only wiped out but the area became surplus in fodder by 1611 tonnes/year mainly in the form of bhusa.

At Sukhomajri (Punjab) integrated watershed management (Grewal 1995) increased farm produced (Grewal 1995) fodder from 730 to 3170 q/year between 1975 (before) and 1988 (after) the project.

8.6 Survival percentage of trees and photosynthetic radiation

In a watershed at Jhansi, having total area of 624 ha, consisted of hills and hillocks, besides only a small area (about 30 ha) in the foot hills was almost tableland (1-3% slope). The hills and hillocks have steep slopes from 8 to 38 per cent.

The hill tops occupied about 10 per cent of the area with 70 per cent of this consisting of slopes. The foot hills account for 10 per cent and wastelands a further 10 per cent. The site was planted with different species of grasses, legumes and trees under wasteland plantation programme. The observations after a period of two seasons indicated that the survival per cent of different trees was 47 at the top of the hills, 81 on hill slopes, 92 in the bottom slopes and 98 in the foothills and plains (Hazra and Singh, 1992). On an average, 80 per cent of the trees survived more than two crop seasons. Similar observations were reported for the canopy coverage study and radiation infiltration (Hazra, 1996 a). The low canopy coverage at the top of the hills is primarily due to restricted growth on the top of the hills which are devoid of any soil and are virtually broken rock masses.

In a study at Indian Grassland and Fodder Research Institute (IGFRI), Jhansi, it was observed that silvipasture system had a tremendous role to play in rehabilitating degraded lands. Eight different tree species when tested (Hazra, 1987) as component of *Cenchrus ciliaris* based silvipasture for their relative efficacy on herbage production against open *Cenchrus ciliaris* pasture (without tree) on the basis of photosynthetically active radiation infiltrating to the ground flora (grasses) indicated that the relative radiation infiltration varied between 58 to 78 per cent with lowest value in *Acacia nilotica* and highest in *Eucalyptus sp.* *Albizzia lebbeck* allowed about 65 per cent, while *A. procera* had 63 per cent radiation infiltration to lower layer. However, though *A. lebbeck* allowed only 65 per cent of radiation gave highest forage yield (95% of relative forage yield as compared to open pasture yield of 100%) besides accounted for the highest leaf litter fall, 3.40 tonnes/ha annually, as compared to *Leucaena leucocephala,* 3.20 tonnes/ha and the values varied between 1.50 to 2.30 tonnes/ha in other trees.

Studies on agroforestry on arable lands with *A. lebbeck* tree species (Hazra, 1994) indicated that lowering down the radiation even by 32 per cent did not have any negative influence on yield of different crops during summer season but such a reduction in radiation during rainy season had a deleterious effect on yield of all crops. Different crops yielded between 52-74 per cent *(Kharif)* and 45-98 per cent *(Rabi)* relative yield of open (without tree) situation. *Trifolium alexandrium* and *Medicago sativa* were found to be most susceptible crops to radiation curtailment as it gave only 45-55 per cent relative yield.

However, experiments conducted in Tamilnadu (Smaraj and Singh, 1993) have shown that groundnut can be successfully grown in the interspaces of both *Eucalyptus tereticornis* and *Leucaena leucocephala* upto three years.

Similarly plant height and dry matter production of fodder sorghum found to be more under the canopy of *Acacia leucophloea* than in the open.

Studies on tree canopy-tntercrop relationship in an agroforestry system at Karnal (Kumar *et al.* 1990) indicates that whole plant concentrations of N, P, K, Ca, Mg, Na, Zn and Fe were high both in sorghum and pearlmillet, when grown under tree canopy as compared to control (without tree), and therefore, intercrop yield reduction was assigned to the above ground competition. Trees having tower type or open canopies would be better for harvesting higher yield of intercrops than trees having spreading type canopies.

8.7 Growth studies of trees

The studies on growth and performance of different tree species at Kharaiya Nala watershed, Jhansi (Hazra, 1996 b) indicated that among eleven tree species, *Leucaena leucocephala* (Subabool) recorded very fast and maximum growth rate having 7.8 m (height), 12.5 cm (collor diameter), 10.4 cm (diameter at breast height) and crown diameter of 2.8 m, after three years of planting, followed by *Eucalyptus* hybrid and *Albizia lebbek* which has shown a good promise specially in foot hills and lower slope of the hills. *Azadirchta indica* (neem) and *Acacia nilotica* having least canopy spread (Crown diameter 1.3 m) and reasonably good growth (3.9 m height, 6.0 cm collor diameter, 5.4 cm diameter at breash height) would be preferred for agroforestry system, which has been further substantiated by the experimental results in Pilani (Samraj and Singh, 1993) that the plant height and straw weight of grain sorghum CSH-1 was more under the canopy of *Azadirachta indica* (neem).

8.8 Fuelwood production

Integrated watershed management in the Kharaiya Nala at Jhansi (Hazra *et al* 1996) revealed that fuel wood availability increased drastically from 320 tonnes/year (pre-project phase) to 2440 tonnes/year during the post-project phase within a short time span of three years. The increased availability of fuelwood became possible as a result of tree planting on field bunds and aiding natural regeneration of old root stocks of different species on the hill slopes of the common lands.

9 Livestock composition influenced by watershed development

9.1 Changes in livestock composition

Livestock is an important activity in rainfed agriculture. People used to keep low yielding local cow, sheep and goat with less buffaloes. The cow, bullocks, sheep and goats were left for grazing on community lands which was having sparse vegetation. Increased assured fodder production through integrated

watershed management and consistent farmers persuation results in drastic change in scenario different watersheds (Grewal 1995, Sharma *et al* 1995, Hazra *et al* 1996, Singh and Singh 1987, Hazra 1996 e, Dhyani *et al* 1993 Jodha 1985 Srivastava and Kaul, 1994). The farmers found to opted for rearing of buffaloes and good breed cows and bullocks. Grazing was completely replaced by stall feeding. Enhanced fodder production facilitated to feed increased number of buffaloes, even though the buffalo is a heavy forage consumer as compared to cow, and results in significant increase in milk production.

The results of integrated watershed management at Jhansi (Hazra *et al* 1996) observed that while there was an apparent increase in the number of buffaloes, other livestock exhibited a decrease in their numbers. The decline in the sheep population was particularly steep, which was due to the fact that mostly landless and marginal farmers were formerly keeping sheep and goats which had free acess to common grazinglands in watersheds. As a results of project intervention, lands which were hitherto lying waste were reclaimed and brought under cultivation and grazing was stopped in common lands under regeneration, thus reducing in grazing space and depletion of the forage potential outside the microwatershed have made difficult for sheep and goat owners to productively maintain large numbers of animals and therefore they disposed of part of their stock. Assured availability of fodder, as a result of reseeding of common lands and field bunds with high forage yielding grass and legume species, paved the way for the farmers to go in for increased number of buffaloes, whose high milk yield, with high fat content, fetches high market price.

9.2 Milk production

Besides increase in crop productivity, integrated watershed management at various places becomes a boon to the milk industry. In general, all watershed management leads to the increase in milk production by 2 to 5 folds, particularly because of enchanced number of buffaloes due to substantial rise in forage yield (Jodha 1995, Singh and Singh 1987, Dhyani *et al* 1993, Grewal 1995, Hazra *et al* 1996).

10 Soil productivity/ fertility build up due to watershed development

10.1 Arable area (cropped)

Soil and water conservation measures at Gaharwa watershed (Hazra and Singh, 1992) and Kharaiya Nala watershed (Hazra, 1996 le) improved soil fertility as well as soil productivity considerably three years after the treatment. Soil organic carbon (percent), available nutrients (kg/ha) N, P and K increased

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10 Soil productivity/ fertility build up due to watershed development

10.1 Arable area (cropped)

Soil and water conservation measures at Gaharwa watershed (Hazra and Singh, 1992) and Kharaiya Nala watershed (Hazra, 1996 le) improved soil fertility as well as soil productivity considerably three years after the treatment. Soil organic carbon (percent), available nutrients (kg/ha) N, P and K increased to

the levels of 0.6, 160, 14, and 167, respectively in treated cropped lands as compared to 0.4, 140, 10, and 128, respectively in untreated one. The substantial reduction in electrical conductivity from 0.4 (untreated) to 0.3 (treated) point towards the improvement. Increase in soil moisture regime due to soil and water conservation measures was also noted.

Increased availability of firewood as a result of integrated watershed management brought significant change in fuel consumption pattern, thus enabling farmers to divert substantial quantity (2053 tonnes/year which is four times higher than the pre-project phase) of the much needed cowdung to crop lands as manure which resulted in the availability of 120, 35 and 170 tonnes/year of N,P,K fertilizers besides improvement in soil physical properties and soil productivity.

10.2 Non-arable area (Pasture/silvipasture)

The grasses have tremendous restorative properties specially for the rehabilitation of the degraded soil. It is not only that the grasses once planted on highly eroded and degrated sites continuously reduce the soil and water loss depending upon the growth and canopy coverage but also, as progressively as the time passes, the vegetation itself helps in improving the soil physico-chemical conditions which in turn help to contain further runoff and soil loss. Almost all studies indicated that the grasses improved the water stable aggregated (Chatterjee and Sen 1964, Hazra and Singh 1992, Hazra and Singh 1994). The improved practices for grassland and further improved measures like silvipasture greatly appreciated the soil organic matter, pore space, bulk density, aggregate stability, field capacity and infiltration rate besides available N,P,K and S as compared to degraded lands, barren hills and hillocks (Hazra 1995 a). Herbage yield from grass-legume pasture (without tree) was higher but the overall soil productivity was much better with silvipasture (Hazra 1995 a). Hadimani *et al* (1972) reported the beneficial role of several grasses and their diversity in relation to root characters and their effect influencing stability rating of aggregates and water infiltration rates into soils.

11 Natural resource conservation due to watershed development

The neglect of the soil has led in the past to the disappearance of once flourishing civilzations. Thus the future of a country and its teeming millions depend to a large extent on the conservation of land. The detorioriation of natural resources in an area can be contained and the total resources properly

developed only by adopting the integrated watershed approach. The basic unit of development is a watershed, which is a manageable hydrological unit that covers the whole area, starting from the highest point of the area (ridge line) to the outlet of the 'nalah' or the natural stream. Integrated watershed management aims at development of all associated components in a watershed, on the basis of each of the toposequences, according to its capability, ensuring best possible management system for conserving natural resources, in such a manner that it yields the best that it is capable of, whether this is in the form of crops or trees or grasses.

Bundelkhand region of Uttar Pradesh once covered by beautiful forest and known for its very useful forest species of multi-usage, lead to highly degraded state with denudated hills and hillocks, because of removal of vegetation and uncontrolled grazing. The situation worsen further through degradation of cultivated land due to increased runoff leading to soil erosion and environmental damage. Conservation of natural resources on integrated watershed basis at Jhansi (Singh *et al* 1996) consequently has resulted in increase of productivity by 13 times which account for surplus in food, fodder and fuel by 18, 14, and 28 thousand metric tonnes, respectively; besides improvement in water resources, soil health, ecology, socio-economic status of habitants and decrease in soil loss (by 77%) and runoff loss (by 59%) after three years.

The fragile ecosystem of Shivalik foothill is characterised by heavy soil erosion, runoff loss, fertility depletion, low crop yields, fuel and fodder scrcity, deforestation of hills, poverty and resource starvation. The consequence of serious land degradation are manifested through frequent droughts, floods, siltation of reservoirs. The extinction of plant and animal species, reduced biodiversity and productivity have become matters of serious concern to such an extent that sheer needs of sustenance forced the poor villagers to decimate the very base of their survival (i.e. natural resources). The isolated efforts made through decades for environmental conservation and protection have failed to produce tangible results (Grewal, 1995). An integrated watershed management helped in rehabiliation of degraded Shivaliks. Rainwater harvesting and its use from small forest catchments when supplemented by integrated farm development could stabilize crop yields and moderate the effect of droughts and floods besides reducing the sediment load from 150 tonnes/ha/year in 1974 to only 15 tonnes/ha/year in 1989 (Bansal and Grewal, 1989). The economic dividents in terms of increased crop production prompted the local farmers to get organised into cooperative societies and shoulder the responsibility to protect the

forests against grazing and illicit cutting. The complete protection of the forest catchments by the local people has resulted into marked improvement in tree cover and grass yield. The hills have regained the vegetation cover and economic condition of the farmers have considerably improved.

Supper-imposing contour trenching in grassed waterways at Agra (Sharada *et al* 1982) found to be effective not only in controlling runoff and soil loss but it also helps in increasing the biomass production per unit area. Grassed waterways along with checkdams at suitable locations in the agricultural watershed reduced run off per cent from 87 to 1.7 of rainfall while soil loss reduction is 92. Similarly, field bunds constructed in agricultural watershed resulted in negligible runoff and soil loss (Narayana 1993).

12 Socio- economic aspects of the watershed development

Soil and water conservation programme on watershed basis generates four kinds of benefits i.e. economic, protective (ecological), environmental and employment generation. All costs involved at different points of time in the watershed project can be quantified in monetary term. The quantification and computation of benefits of a watershed development project is rather difficult, as benefits are both direct and indirect. Direct benefits are quantified in monetary terms and may include increased production of food, fibre, fodder, fuel timber, milk, fish and increased employment. Intangible benefits as erosion control, ground water recharge, environmental benefits etc. may be present. In addition, multiplier effect may generate new investment opportunities in transportation, schools, banks and consumer stores etc. Due to non-avvailability of data on indirect benefits and techniques to convert them into monetary value, it is difficult to consider all the benefits/costs aspect of soil and water conservation programmes. However, considering above limitations, it has been opined (Ram Babu and Agarwal 1990) that for economically sound project, the benefit cost ratio should not be less than 1.20.

12.1 Employment generation

The important aspect that needs to be considered in the overall impact of the watershed for the rural people is the employment generation for these people. About three times increase in human employment as well as bullock labour was reported due to watershed management programme at Kharaiya Nala (Jhansi) besides creating 8760 man days/year on accounts of protecting 665 ha common lands (spread over the seven micro-watersheds) for regeneration

(Hazra 1996 e, Hazra *et al* 1996). On an average, both human employment as well as bullock labour increased three fold over base year (Hazra, 1997).

12.2 Income for rural poor/landless people

The income of landless family found to be increased from a meagre sum of Rs. 2280/- per family annually during pre-phase period to Rs. 14000/- per family annually after three years implementation of watershed management project (an increase by over 600%) that also includes plate making *(Dona)* from leaves of 'Dhak' *(Butea monosperma)* and basket making by using unwanted minor bushes mostly *Lantana camera* (Hazra and Singh 1992). Similarly, the income of farm family rose from Rs. 2900/- to Rs. 22910/- per family annually during the same period.

12.3 Direct/indirect gains

Watershed management programme not only ensure conservation of natural resources on sustainable basis but provides much needed food, fodder, fiber and fuel in sufficient quantities, besides improving socio-economic status of its habitants, through creating avenues for innumerable subsideiary sources of income, like fishery, small scale industries, like basket and plate making from vegetative produce (leaves, unwanted bushes etc.). Integrated watershed management ensured sufficient fodder abailability thus help to check cattle migration. It also stop migration of village labourers by generating extra employment at village level itself and thus help in utilizing village manpower more efficiently and meaningfuly.

Integrated watershed management leads to the development of location specific low cost technology, as for example, a new system of feeding milch cattle has emerged at Sukhomajri (grass/sorghum stalk on a frame made of wooden poles, prevent humification of grass, eliminate the damage by rats, and helps in proper aeration. From December onwards, berseem and stacked dry forage is choped together in 1:4 ratio to fed the milching buffaloes).

12.4 Benefit-cost ratio

Economic evaluation of soil and water conservation measures at Tehri-Garhwal (Dhyani *et al* 1990) considering 25 years project life and 10 per cent discount rate, utilising 14 years data (1975-88) revealed that irrigated agriculture gave maximum benefit cost ratio of 2.41 followed by orchard plantation (1.99), rainfed agriculture (1.74) and fuel-cum-fodder plantation (1.64) leading to an overall benefit cost ratio of 1.93. Systemic economic analysis

conducted at Central Soil Water Conservation Research and Training Institute (CSWCRTI), Dehradun, and its Regional centres on the benefits that can be derived from utilisation of the degraded lands for fuel and fodder production shows that in all the cases the benefit cost ratio is more than 1.4 (Narayana, 1993). In most cases, benefit cost ratios are found to be much higher (highest being 4.0 with Eucalyptus fuel alone at Ootacamund) indicating thereby conversion of the denuded lands into fuel-cum-fodder areas is economical. Afforestation of hillocks and degraded wasteland sites at Gaharwa watershed (Jhansi) found to be highly cost effective since the forage benefit alone (Rs. 3100 per hectare) is sufficient to pay back the entire cost of land treatment including afforestation in one year (Hazra and Singh, 1992). Appropriate soil and water conservation measures and silvipastoral approach in reclaiming highly degraded wastelands, found to be sustainable and comparable to agricultural crop productivity on good arable lands, giving a benefit cost ratio of 2.89 (Hazra and Singh 1994).

12.5 Village level institution building

It is now widely accepted by both academicians and practitioners all over the world that people's participation is essential for the success of soil and water conservation programmes. The India's experience time and again shows that all successful projects backed by the active participation of people's. Therefore, it becomes imperative to motivate village peoples and to train them and thereby to empower them so they could identify their problems and resolve them on their own eventually leads to the development of village-level institutions or organisations. The research providers and/or development agencies could trigger such action through the catalytic role.

12.6 Peoples participation

Unless the programme beneficiary (Farmers) are convinced that it is in their own personal interest to protect their soil from erosion and to harvest, store and conserve rainwater and spend their energy and money in construction, and repair and maintenance of necessary soil and water conservation structures, no soil and water conservation programmes can succeed.

The majority of rural people in most of the third world have heavy load (self and social demands by a perosn to maintain a minimum level of autonomy) and little power (resources such as abilities, possessions, position, allies, etc. which a person can command in coping with the load) to cope therewith, and

hence, they are too preoccupied with mere survival to participate meaningfully in development activities (Lupanga, 1988).

In Sukhomajri, the farmers did not participate initially because there was a lot of uncertainty about the quantum of returns and there was no assurance that the promised returns would in fact accrue to them and the expected costs in terms of benefits that were to be foregone by not grazing their animals in common property lands were high. But afterwards, when a water users' society was established in the village and equal distribution of reservoir water was assured by the society, and when they assured by the society, and when they themselves saw that crop yields and milk yield had increased markedly, they came forward and participated in the project. The project interventions helped in increasing the expected returns (power) and reducing them expected costs (load). Similarly, in all the other successful cases, the project interventions were aimed at either enhancing the expected return or reducing the expected costs or both directly and/or indirectly.

The secret of success of some of the watershed projects like Sukhomajri, Tejpura, Daltonganj, in the core sector practice of water pond and other water harvesting and water conveyance and application practices and protection of plantations and regeneration of green cover on baren lands lies on social fencing by the villagers themselves (Dhawan, 1992).

Soil and water conservation programme which lies near the village and depends for its success on their participation should become that of the village and its is they who whould select the priorities and the location of works (Bali, 1995).

CHAPTER-3

MATERIALS & METHODS

MATERIALS AND METHODS

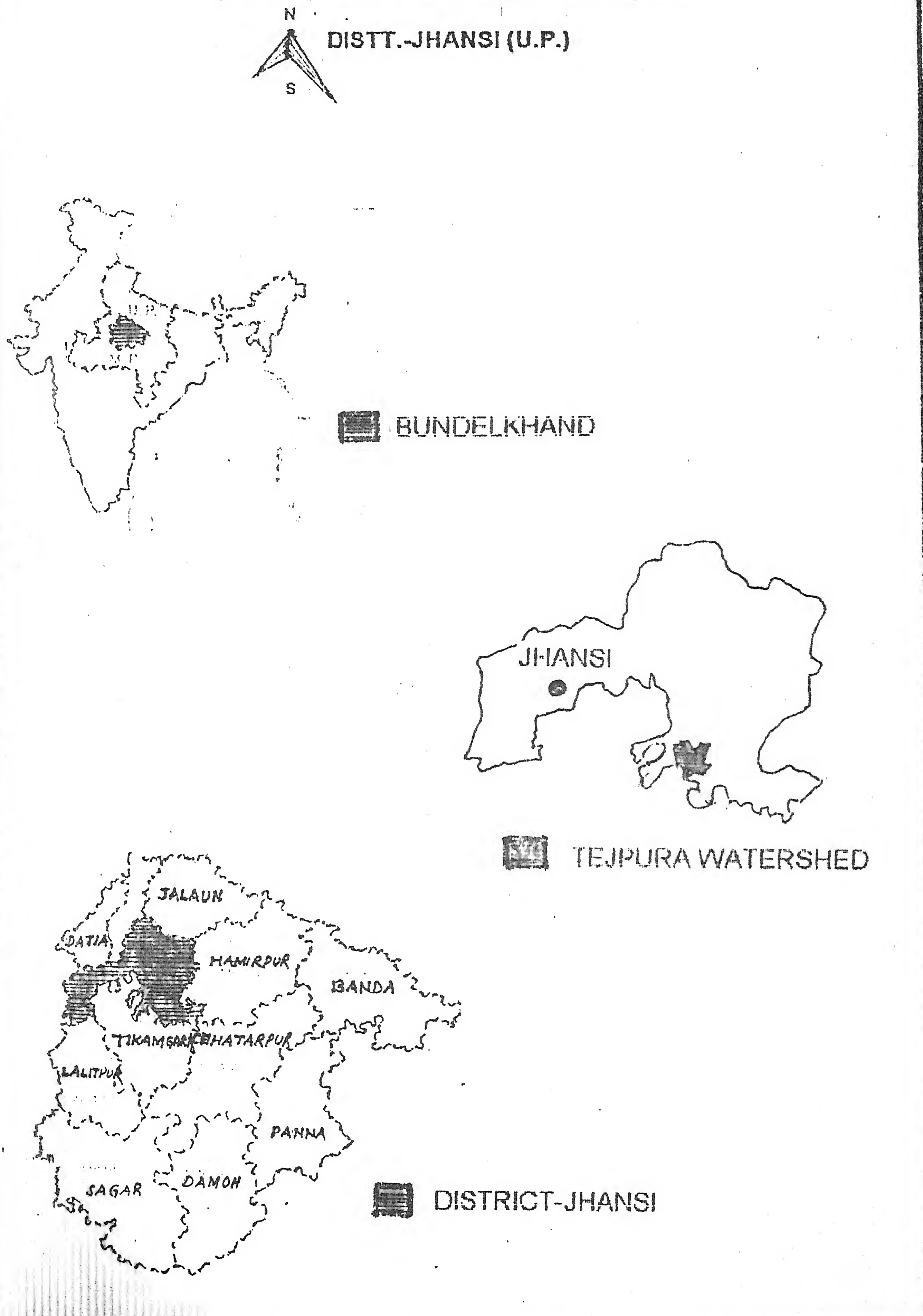
In this chapter described the materials used and methods followed for the study entitled, "Integrated Natural Resources Conservation on Watershed basis for Increasing Producitivity". The study was based on the integrated watershed management basis at Tejpura village. The study is located in hilly area towards south of Jhansi-Mauranipur road at about 45 km away from Jhansi city. It is situated at $25^0 15'$ N latitude and $78^0 58'$ E longitude and is 240 metre above mean sea level. Tejpura watershed covers a total area of 775.7 ha and consists of 5 sub watersheds. Slope of the watershed ranges from 1-10 per cent. The area is drained by river Lakheri which is a tributary of Betwa river from South-east to north-east in V-shaped form. the location is given in the map (Fig. I). The soil and water conservation measures were taken up on the completion of the basis survey work of the watershed area with respect to vegetation, soil, climate etc. The details of the survey will appropriately be mentioned in the subsequent text.

3.1 Climate

The climate of the area is semi-arid with mean maximum and mean minimum temperature of 31.8^0C and 18.7^0C, respectively. The mean summer temperature is 33.3^0C and mean winter temperature is 16.1^0C the period between April to June is very hot (maximum temperature reaching upto 45^0C in June). The average relative humidity is 55 per cent in the morning and 40 per cent in the evening. Frost occasionally occurs in the winter months of December and January. The mean annual rainfall is 925 mm. The potential evapotranspiration is about 1520 mm. The area experience drought spells almost every year.

Maximum rainfall is received in the month of August. The monsoon normally starts around last week of June and terminates by end of September. Pre-monsoon showers are often received during first three weeks of June. High intensity rains are often received in this region. In 5 year return period 135 mm, 190 mm and 227 mm rainfall is received in one, two and three days, respectively. The rainfall pattern is highly erratic and long drought spells occur during *kharif* season. Monthly distribution of rainfall recorded at the site is given in Table 1.

PROJECT LOCATION MAP
TEJPURA WATERSHED



3.2 Description of soils

During the course of survey 4 soil series A,B,C and D were identified which were correlated with soil series namely Haripur, Khairar, Nahari and Kindhuli, respectively. These soils were earlier mapped in Bundelkhand region of U.P. during reconnaissance soil survey of Banda and Hamirpur districts. Brief description of the soil series and mapping units encountered in the area are presented below:

3.2.1 Haripur series (H)

Area : 289.50 ha i.e. 37.32%

Classification : *Vertic Ustochrepts*

Soils of Haripur series are very deep, moderately well drained, dark greyish brown to dark brown silty clay loam to silty clay with cracks on the surface. They occur on nearly level to very gently sloping old flood plains. These soils have good water holding capacity and high fertility potential. The main problem of these soils is low sub soil permeability resulting in excess wetness during monsoon. The soil surface gets saturated quickly due to slow internal drainage causing considerable run off, sheet and rill erosion besides poor aeration for plants. Following 9 phases of this series were mapped:

HkB1-	Haripur silty clay on 1-3% slope, Slightly eroded
HgB2-	Haripur silty clay loam on 1-3% slope, moderately eroded
HcB2-	Haripur, sandy loam on 1-3% slope, moderately eroded
HdB2-	Haripur loam on 1-3% slope, moderately eroded
HfB2-	Haripur, clay loam on 1-3% slope, moderately eroded.
HkB2-	Haripur, silty clay on 1-3% slope, moderately eroded
HcC2-	Haripur, sandy loam on 3-5% slope, moderately eroded
HgC2-	Haripur silty clay loam on 3-5% slope, moderately eroded
HkC2-	Haripur silty clay on 3-5% slope, moderately eroded

3.2.2 Khairar Series (K)

Area : 240.30 ha i.e. 30.98%

Classification : *Vertic Ustochrepts*

Soils of Khairar series are very deep, moderately well drained, dark greyish brown to dark brown silty clay loam to silty clay calcareous soils occurring on very gently to gently sloping old flood plain. These soils have good water holding capacity with medium production potential. Main problem of these soils is excess wetness during monsoons due to low sub-soil permeability. These soils have problem of tilth and require high draft. There are lime 'Kankars' throughout the pedon which impeds downward water percolation. Following 7 phases of the series have been mapped.

KkB1-	Khairar, silty clay on 1-3% slope, slightly eroded
KkB2-	Khairar, silty clay on 1-3% slope, slightly eroded
KdB2-	Khairar, loam on 1-3% slope, moderately eroded
KgB1-	Khairar, silty clay on 1-3% slope, moderately eroded
KkC2-	Khairar, silty clay on 3-5% slope, moderately eroded
KgC2-	Khairar, silty clay on 3-5% slope, moderately eroded

3.2.3 Kindhauli series (Kn)

Area : 116.43 ha i.e. 15.01%

Classification : *Typic Ustochrepts*

Soils of Kindhauli series are very deep, well drained, dark yellowish brown to dark brown, loam over clay loam or gravelly clay loam, occurring on gently slopping to moderately sloping undulating/dissected flood plain lands. These soils are calcareous. These soils are subject to moderate to severe erosion and have abundant lime nodules throughout the depth. Major limitation of these soils is severe erosion leading to formation of narrow gullies. These soils have

somewhat low water holding capacity, low organic matter content and poor fertility. Following 6 phases of the series have been mapped.

KnB2-	Kindhauli, loam on 1-3% slope, moderately eroded
KncC3-	Kindhauli, sandy loam on 3-5% slope, severely eroded
KndC3-	Kindhauli, loam on 3-5% slope, severely eroded
KnfD3-	Kindhauli, clay loam on 5-10% slope, severely eroded
KndD3-	Kindhauli, loam on 5-10% slope, severely eroded
KngC3-	Kindhauli silty clay loam on 3-5% slope, severely eroded

3.2.4 Nahari series (N)

Area 70.20 ha i.e. 9.05%

Classification : *Udic Ustochrepts*

Soils of Nahari series are very deep, well drained dark yellowish brown to dark brown, clay loam, occurring on very gently to gently sloping lands. These soils are mostly cultivated. These soils have good water holding capacity, low organic matter content and medium fertility. Following 3 phases of the series have been mapped :

NfB1-	Nahari clay loam on 1-3% slope, slightly eroded
NcC2-	Hahari sandy loam on 3-5% slope, moderately eroded
NdC2-	Nahari loam on 3-5% slope, moderately eroded

Soil, physiography and hydrology maps of Tejpura watershed are being presented in Appendix 1, 2 and 3, respectively. The details of land capability and irrigability classification have been given in Appendix 4, and 5, respectively.

3.3 Geology and natural vegetation

The major portion of the watershed comes under recent alluvium of river Yamuna and its tributaries. Some portion of the area covering hillocks comprises

coarse grained granites and granite gneisses called Bundelkhand gneisses overlying granite basement.

The vegetation of the area is scanty due to felling of trees and shrubs for fuel. Natural vegetation has almost disappeared due to cleaning of land for cultivation. As such there is little land left for grazing of the animals. About 30.5 ha of the watershed area is under protected forest supporting no vegetation and was in the highly degraded state.

Common tree species

Hindi name	**Scientific name**
Neem	*Azadirachta indica*
Babool	*Acacia nilotica*
Shisham	*Dalbergia sissoo*
Jamun	*Eugenia jambolana*
Dhak	*Butea monosperma*
Mahua	*Madhuca indica*
Khair	*Acacia catecheu*
Ronj	*Acacia leucocephala*
Kardhai	*Anogeissus pendula*
Kanju	*Holopetelea integrifolia*

Common fruit trees

Aonla	*Embelica officianialis*
Karaunda	*Carissa congesta*
Ber	*Zizyphus numularia*
Mango	*Mangifera indica*
Custard apple	*Annona squamosa*

Grasses

Doob	*Cynodon dactylon*
	Aristida sp.
Kans	*Saccharum spontaneum*
	Eremopogon foveolatus, Themeda sp.
	Heteropogon contortus
Legumes	*Indigofera sp.*
	Atylosia sp.
	Clitoria sp.

3.4 Village statistics

The watershed falls under a single village of Tejpura covering about 775.6 ha of the total land area, of which 525.6 ha is under cultivation that is nearly 67.7 per cent.

The villagers derive their irrigational requirements through private tube wells covering 8.0 ha and with dug well for 12.0 ha, which is meagre less than 4 per cent of the cultivated area under irrigation. The ground water table fluctuates between 3.5 to 5.0 m in rainy season, 6-8 m in winter and 10-15 m and above during summer months. The ground water is suitable for drinking and irrigational purposes. The possibility exists for using ground water for irrigation by boring shallow and small tube wells and boring swamp tube wells. It is also feasible to construct farm ponds and small water harvesting bandhi and also check dams on the seasonal nallhas. It is possible to use water from these nallhas for irrigation purposes through different lifting devices.

The village has 450 families including 183 schedules caste families. There are about 500 unskilled labourers available in the locality with about 130 seassonal migratory labourers. There is no small industries in the vicinity of the village.

The nearest township is Mauranipur about 10 km away from the operational site. There are 102 small farmers with 2-3 ha of land, 127 marginal farmers with 1-2 land and 90 farmers below 1 ha land. The average holding per family is 2.1 ha.

3.5 Initial Land Use

Out of total area of 775.7 ha in the watershed about 525.6 ha is cultivated. Land use pattern of the operative area is presented in table 2.

The general physiography of the area with respect to slope is given in table 3.

The soils are generally medium to heavy soils with about 325.5 ha under sandy loam, loam and silty loam and about 450.1 ha under silty clay loam and clay loam soils. There was some problem of waterlogging in the lower reaches of the watershed. Initial cropping practices are indicated in table 4.

Table 2: Initial land use pattern of Tejpura watershed

Description	Area (ha)
Area under cultivation	
i) Irrigated	20.2
ii) Rainfed	505.4
Wasteland	
i) Cultivable	25.6
ii) Non-cultivable	20.8
Permanent pasture and grazing lands	5.5
Forest	
i) Reserve	46.9
ii) Private	17.7
Bare hillocks and rock outcrops-	
Present fallow 68.20	
Miscellaneous land 65.40	
(road, path, nala etc.)	

Table 3 : Area under different slope at Tejpura Watershed

Slope (%)	Area (ha)
1	20.0
1-2	40.7
2-3	473.2
3-5	110.2
More than 5	131.6

Table 4: Initial cropping practices at Tejpura watershed

Crop	Area (ha)	
	Irrigated	Rainfed
Sorghum + Pigeon pea	-	105.5
Seasame + Black gram	-	8.2
Paddy	-	2.3
Wheat	20.2	190.2
Gram	-	86.4
Barley	-	5.5
Mustard	-	15.8
Pea	-	1.5

3.6 Initial Crop Productivity

Pigeon pea during kharif season, wheat and gram during rabi season were the principle crops of the watershed area. Other crops of marginal importance were Mustard, Barley, Pea, Sesamum, Black gram and Paddy. Survey of the area reveals that the general crop yield are very poor i.e. 2.0 q/ha of Pigeon pea, 1.0 q/ha of Sesamum, 2.0 q/ha of Black gram, 12.0 q/ha of Paddy, 9.0 q/ha of wheat, 6.0 q/ha of Gram, 3.0 q/ha of Mustard, 10.0 q/ha of Barley and 3.0 q/ha from Peas. These crops were basically raised on rainfed situation without any fertilizer application. Very limited area (20.2 qa) was under irrigation from dug out wells and a paltry application of 20 kg nitrogen was given to the crop of wheat under irrigated condition. The farmers were mostly using the traditional varieties and hardly any improved varieties were observed to be growing in the watershed area.

3.7 Soil Conservation Survey and Planning

As the slope of this area ranged from 1-10% and due to high intensity rains run off water caused severe sheet, rill and gully erosion. The gully heads were moving at alarming rates as runoff water from barren hills enters the cultivated fields. The extent of soil erosion problems were as follows :

a) Area affected with sheet erosion-165.0 ha
b) Area affected with rill erosion-449.2 ha
c) Area affected with gully erosion-110.2 ha

As all the water flew out of the watershed, only a few hectare area was irrigated by open wells having very low recupuration rates. Keeping in view the above problems the following soil and water conservation measures were undertaken based on actual contour survey work (Fig 2 and 3). Studies were also made on the effect of land levelling and bunding on the yields of some selected crops. Following soil and water conservation measures were undertaken :

3.7.1 Diversion channels (community work)

Runoff water from barren hills which enters into cultivated filed were diverted through diversion channels made at the foot of these hills. These channels were protected by planting grasses. Run off water from these diversion channels were discharged into natural nallha through Chute spillways. As shown in plan map, 1000 m diversion channel were proposed. Details and average cross section of these channels is given in Appendix 6.

3.7.2 Contour bunds (Individual work)

For reducing amount and velocity of run off contour bunds were constructed. As the slope of the cultivated fields varies from 2-3 per cent, a horizontal interval of approximately 60 metre is kept. A total of 4250 m contour bunds were constructed in the sub watershed. Details of cross-section is given in Appendix 6.

3.7.3 Submergence bunds (Individual work)

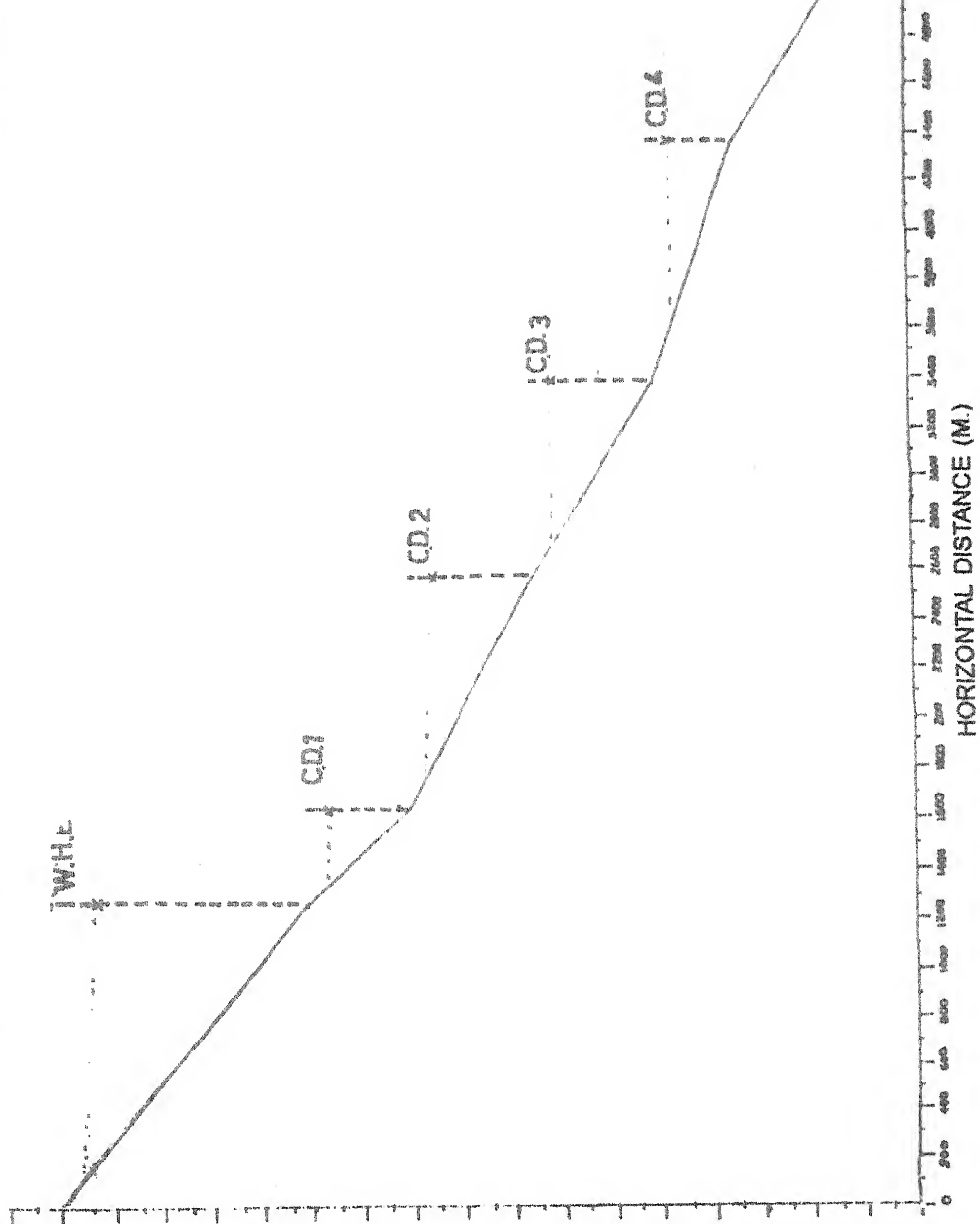
To prevent rill and gully erosion bunds of 4.5 m^2 cross section were provided to submerge water in the depressions. These depressions were filled by soil to save high cost of levelling these depressions. These submergence bunds were provided with proper outlets to carry out the excess run off water. A total of 5150 m submergence bunds were constructed. Details of cross-section is given in the Appendix 6.

3.7.4 Gully plugs (Community work)

For control of gully erosion and grade stabilization drop inlet spilways were provided at appropriate site to provide a temporary storage above the inlet and therefore the design discharge capacity of these structures is reduced. This reduction of discharge resulted in a lower peak channel flew below the structure. Four gully plugs were constructed in the sub-watershed. Details of the gully plugs are given in Appendix 7.

FIG. - 2 : INTEGRATED WATERSHED DEVELOPMENT PLAN
KHARAIYA NALLAH TEJPURA (JHANSI)
SCALE 1" = 1320'

FIG. - 3 : LONGITUDINAL SECTION OF KHARAIYA NALLAH



3.7.5 Chute spill ways (community work)

For the safe disposal of excess run off water from the contour and submergence bunds, Chute spillways and pipe drop inlet structures were provided. Design details of these *pucca* outlets are given in Appendix 8 and 9.

3.7.6 Check dams (CD) - (Community work)

Almost all the area is rainfed as regard to *rabi* crops. As all the water flows out from the sub-watershed only a few hectare area receives life saving irrigation from the existing open wells in *rabi* season. These wells have very low recoupation rates.

In the absence of a site for farm pond and unwillingness of farmers to give land for dug out pond, run off water were retained in the existing nallha by providing masonary check dams across the nallha. This retained water was used for irrigation of *rabi* crops. In case of prolonged drought spell in the *kharif* season, this water can be used for irrigation of kharif crops too.

From the upper reaches in which a water harvesting dam has been constructed, two small nallah is coming out from the eastern side and another from the western part and in a 'Y' shaped form make a single nallah and leaves from the south-east corner of the watershed to north-east corner in a 'V' shaped form in its running level of 7 km. On its run of the nallah, four masonary check dams were constructed across the nallah at a vertical interval (VI) of 3.5 metre each. These four check dams impounds about 13 ha m. The engineering details of the structure are given in Appendix 10 and 11.

As the foundation is pervious, aprons were provided on upstream and downstream sides to prevent seepage. A rectangular gate was provided in the centre. This gate was kept open during rainy season to avoid any silt deposition in the nallha bed.

3.7.7 Water harvesting dam (WHD) - (Community work)

The location of the watershed area and the natural ridge lines that is available in the upper reaches on the south-east corner of the watershed. The hills froms the major ridgelines watershed areas which contribute to the major protion of the water to the watershed. Taking the advantage of the hills, two hillocks distant at 350 m apart were inter connected with the help of earthern bunds as indicated in Appendix 12.

The surplus water from the dam was drained by pipe drop inlet structure and emergence spillway. The engineering details of these structure are given in Appendix 13 adn 14. The average water impounds capacity of the dam is 12 ha m with submergence area of 16 ha.

3.8 Crop Production and Management under dryland condition

Several of the improved crop production technology and practices suitable for dryland agriculture were tested for improving the productivity under rainfed situation as detailed below.

3.8.1 Performance of crop and varieties

Six *kharif* and four *rabi* crops were considered for their varietal evaluation for possible use in the watershed area. The *kharif* crops are sorghum, pigeonpea, black gram, green gram, soybean and groundnut; while the *rabi* crops were wheat, gram, peas and mustard. These crops were tested for 2 consecutive crop seasons from 1987-88 to 1988-99. The details of the varieties are indicated in the respective tables (5 to 14) in the Chapter'Results & Discussion'.

3.8.2 Intercropping Studies

Crop mixture/intercropping is an important practice in dryland situation for ensuring against fluctuations in crop productivity and also failure of crops. Two important intercropping studies are made on main crops like sorghum during *kharif* and gram during *rabi.* The treatment details (Table 15 and 17) are specifically presented in the Chapter 'Results and Discussion' in respective sections.

3.8.3 Sequential cropping

In the dryland areas, it is often a single crop is being practices. It is difficult to grow the second crop because there is hardly any moisture left in the profile for the germination. However, with the selection of appropriate crop during *kharif* season with proper duration, possibility exists to raise the second crop. It is with this intention, a sutdy was made to see the possibility of growing second crop in a season under dryland condition. The short duration *kharif* crops were taken up such as fodder sorghum and cowpea followed by *rabi* crops like gram, mustard, wheat and barley. The treatment table 20 in the chapter 'Results & Discussion.

3.8.4 Tillage practices

Tillage is a very important practice in rainfed situation specially for increasing the infiltration of rain water and recharge of subsoil layers. A study was made by using different shall tillage machines against deep tillage machines on sorghum crop (cv. Mau T-1). The deep tillage treatments once applied, the plots were maintained as such for 3 years to see the effectivity of the ploughing for longer years. However, the shallow ploughing were done every year. No *rabi* crop was taken on those plots. The crop was fertilized with recommended level. The treatment details are enumerated in table 22 as presented in chapter 'Results & Discussion'.

3.8.5 Fertilizer Use Studies

Nitrogen is the most critical nutrient input for dryland crops. The split application of nitrogen is also found to be beneficial instead of applying the full fertilizer basally. A study was thus conducted to see the effect of split application of nitrogen on the productivity of sorghum with the recommended level (80 kg N/ha).

3.8.6 Mulching Studies

Water is the most limiting factor for the germination, growth and productivity of dryland crops. The most critical factor is the plant stand which is controlled by the germination of the seeds which is entirely dependent on the status of moisture level in the seed zone. The study was thus conducted with four types of mulching materials namely dry grass @ 5 t/ha, sorghum stalk @ 5 t/ha, Rice husk @ 5 t/ha and soil mulch 3 to 4 cm against control (no mulch treatment).

3.8.7 Single Supplemental Irrigation

Application of small amount of water does a miracle in improving productivity under dryland situation. It is therefore, an experiment was planned to study the effect of single supplemental irrigation on some selected crops namely sorghum, pigeon pea, groundnut and soybean. Four levels of irrigation (no irrigation, 25, 50 and 75 mm) were applied to these crops at active growth stage/pre-flowering stage during the most moisture stress situations.

3.9 Crop production and Management under Irrigated condition

Irrigation resources was developed in the watershed area because adoption of appropriate soil and water conservation measures including water

harvesting and storage of rain water. There is also an increased underground water resource development because of increased recharge due to the adoption of soil and water conservation practices. This helped in the development of dug out wells for irrigation purposes. Thus with the changed water availability and irrigation resources, scnerio in crops and cropping practice have also been greatly changed. To commensurate with the change in the cropping practices, several studies were initiated for crops and crop management for their suitable utilization in the watershed area.

3.9.1 Crop rotations

A study was conducted to find out the sutiability of some crops in a sequence for double cropping in the area which have also been combined with 3 fertility levels. The crop rotations are sorghum followed by wheat, sorghum followed by gram, and groundnut followed by wheat, while fertility levels are 50% of recommended fertilizer dose to *kharif* crops + 50% to *rabi* and 100% fertilizer dose to both the crops. The experiment has been conducted in RBD with 3 replications.

3.9.2 Fertilizer Studies

Two studies were conducted on gram and mustard crops with different levels of Phosphorus and Sulphur. In case of gram, the treatment combinations were of 4 levels of P (0, 20, 40 and 60 kg/ha) combined with sulphur (0, 20 and 40 kg/ha); whereas in case of mustard 3 levels of P (0, 20 and 40 kg/ha) combined with 4 levels of sulphur (0, 20, 40 and 60 kg/ha). In addition to these, two experiments were also conducted on groundnut and soybean, both are newly introduced crop inthe watershed. In these two crops 4 levels each of P & S (0, 20, 40 and 60 kg/ha) were tried.

Overall fertilizer use scenario in the watershed was also studied, besides evaluating the effect of fertilizer nutrients on yields of some selected crops of Tejpura watershed.

3.9.3 Irrigation studies

Wheat being the most important crop of the watershed, a study was undertaken on the irrigation water management. Twelve treatment combinations were taken up with an opportunity of 1-6 irrigations. The treatment details are given in the appropriate table-39 in the Section 'Results and Discussion'. This experiment was also conducted in RBD with 3 replications.

Another important irrigation study was also undertaken with varying number of irrigations (maximum four) to different crops like wheat, gram, sorghum and groundnut. The treatments details are given in Table - 40 in the section 'Results and Discussion'.

3.9.4 Component Study

The study was conducted on improved varieties of sorghum and wheat vis-a-vis with the traditional varieties in combination with fertilizer and irrigation. The treatment details are given in the table 41 and 42 in the section 'Results and Discussion'. This experiment was also conducted in RBD with 3 replications.

3.9.5 Studies on Soil and Water Conservation Measures

The study was conducted in Randomized Block Design with 3 replications to find out the effect of soil and water conservation measures in relation to the varieties of traditional vis-a-vis improved ones and improved methods of cultivation namely fertilizer and irrigation on important crops like sorghum, wheat, groundnut and gram. The treatment details are given in table 46 in chapter 'Results and Discussion'.

3.10 Water Resource Development

Apart from the conservation of natural resources, water resource development is one of the major activities in the watershed development programme. In the present case also thus a study was undertaken relating to the water resource build up with various harvesting structure constructed for such purpose.

3.10.1 Dug out well

Because of the very low water availability in the watershed area, there were very few number of wells. Initially there were five functional wells and seven wells were non-functional because of non-availability of ground water at that level (20 m). With the changed scnerio of soil and water conservation measures adopted in the watershed area, its effect on number of dug out wells was studied.

3.10.2 Water table depth

A series of studies were undertaken over the years in some selected wells numbering 20 at three different seasons namely Summer (May), Rainy season (August) and winter seaons (January). The average water depth over the

seasons and years have been recorded. At these wells recording has also been made for the recharge of the wells with the help of 7.5 HP diesel pump.

3.10.3 Irrigation water availability and irrigated area

The studies were taken up to find out total irrigation availability from various sources for crop production and also the extent of the irrigated area in different seasons.

3.10.4 Land use, crop intensity and crop productivity

Changes in the land use over the years and also cropping intensity as well as crop productivity were recorded on the whole watershed basis.

3.11 Pasture Development and Afforestation

In the watershed area a small area (30.5 ha) is meant for grazing by animals for the community. The entire community land is located on the hills which was compeletely barren and totally devoid of any vegetation. There were tremendous soil and water loss from the site and affecting the cropped land down below. In the year 1983 a production study from these lands for grassland herbages were made for recording the initial level of productivity from the sites. Twelve quadrats were placed for recording of pasture data and no grazing was allowed in this land.

3.11.1 Soil and Water Conservation measures

For the rehabilitation of the community lands, appropriate soil and water conservation measures were adopted. The first measure conducted was the construction of diversion channel at the foot hill adjacent to the crop land for guiding the high velocity run off safely to the *nallah.* The total length of the diversion channel is 1657 m on the hill slopes (varying between 18-30%). Conservation measures adopted were contour stone bunds, staggered trenches on contour lines, gully plugs and water harvesting pits.

3.11.2 Pasture development

As the initial grassland flora was totally destroyed by over grazing by animals and other biotic interference, the entire area was sown with composite range species like *Cenchrus ciliaris, Pennisetum pedicellatum* and *Stylosanthes hamata.* In the very first year a small amount of Nitrogen and Phosphorus was also applied (20 kg each).

3.11.3 Afforestation

As there was no vegetation like trees and shrubs, the community land was appropriately planned with suitable tree species like *Leucaena leucocephala, Acacia nilotica, Dalbergia sissoo, Azadirachta indica, Albizia lebbeck* etc. About 850 plants per ha were planted in pits of size 0.45 m^3. The excavated soil of the staggered trenches and pits were placed on the lower reaches in a semi-circular fashion so that maximum run off water is directed to the trenches and pits. *Stylosanthes hamata* and also seeds of tree species in two rows were specially seeded on the excavated soils. Both the ends of the staggered trenches were also utilized for the planting of trees.

Regeneration of trees and shrubs from native root stock due to protection has been studied also.

3.11.4 Fertility Studies

The productivity of the grasslands were recorded with the help of 12 quadrats/ha over the years.

3.11.5 Succession of grasses

With the closure of the grasslands from grazing, there is a succession of grasses over the years and changes in the botanical composition of the grasses were recorded from the above cited quadrats.

3.11.6 Growth studies of trees

Trees once planted, the grwoth observations in the form of plant height, collar diameter, breast height diameter and canopy diameter were recorded. The light infiltration in the form of photosyinthetic active radiation were also measured with the help of Quantum Radiometer.

3.11.7 Fodder and Fuelwood Availability

An analysis was made in the year 1993-94 against a backdrop of the base year 1983-84 regarding the change in availability pattern of fodder and fuelwood in the watershed.

3.12 Livestock Studies

Change in livestock composition was recorded in the year 1993-94 against the specieswise composition in the base year of 1983-84. With the changed scenario in forage and feed availability resources in the watershed area, an effort was made to improve the local herds with the introduction of improved

bulls of Haryana and Saliwal breeds. The number improved progenies/animal number was also recorded. The change in the milk yield pattern of both cow and buffalo were also recorded for this period.

3.13 Run Off and Water Loss Studies

Studies were made on run off and water loss from the watershed area before the imposition of any treatment and also after the treatment of entire watershed area on specific land use situations. Two gauging instruments were installed at each of the different land use situations like arable cropped area, pasture area and silvipasture situations. Sediment yield from the run off was also recorded at four locations at the *nallah* on the foreside of the check dams.

3.14 Soil Productivity Studies

Soil physico chemical properties were studied with standard methods for different land use situations over the years. Similarly, the soil fetility studies were also made over the years for farious land use situations.

3.15 Socio-economic studies and other associated changes

Of the 450 farmers in the watershed, 35 were landless, their income generation pattern over the years were recorded. Estimation has also been made for the employment generation in the form of human labour and bullock power. These were also made on the income generation pattern of the farmers of the watershed.

CHAPTER-4

RESULTS &
DISCUSSIONS

RESULTS AND DISCUSSIONS

The experimental results obtained from the investigation entitled "Integrated natural resource conservation on watershed basis for increasing productivity" conducted at Tejpura (Jhansi) watershed are presented and discussed in this chapter.

4.1 Crop production and management under dryland condition

Results of the improved crop production technology and practices, suitable for dryland agriculture, being tested as a part of on farm research, for improving the productivity under rainfed situation, are presented below :

4.1.1 Performance of crops and their varieties

Results pertainig to varietal evaluation of six *kharif* and four *rabi* crops at Tejpura watershed are presented below :

Sorghum : Among six varieties tested under rainfed situation, CSH-5 recorded significantly much higher grain yield (24.5 q/ha) as compared to other varieties, having average yield of 17 q/ha including Mau T-1 and Mau T-2 (Table 5).

Table - 5: Evaluation of sorghum varieties under rainfed situation

S.No.	Varieties	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	604	15.5	19.3	17.4
2.	370	14.1	18.6	16.4
3.	308	14.6	17.7	16.2
4.	Mau T-1	13.4	20.9	17.2
5.	Mau T-2	14.8	19.7	17.3
6.	CSH-5	23.8	25.1	24.5
	CD at 5%	1.9	1.6	

Pigeonpea : 'Pusa ageti' among six pigeonpea varieties tested under rainfed condition gave highest yield of 14.9 q/ha; whereas, 'Prabhat' recorded the lowest (8.9 q/ha) and yield of other varieties ranged between 11-12 q/ha (Table 6).

Table - 6 : Evaluation of pigeon pea varieties under rainfed situation

S.No.	Varieties	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	Pusa ageti	15.5	14.3	14.9
2.	T-7	12.8	12.3	12.6
3.	T-17	12.4	12.3	12.4
4.	T-21	12.4	10.4	11.4
5.	Bahar	10.7	11.6	11.2
6.	Prabhat	9.9	7.9	8.9
	CD at 5%	1.4	N.S	

Blackgram: Under rainfed situation, yield of black gram varieties T-9, P-1 and Pant U-30 found to be at par having average yield of 9.5 q/ha which is significantly higher than the average yield level of 8.0 q/ha recordeed by UPU-19, Mash-64 and Khargone varieties (Table 7).

Table - 7: Evaluation of black gram varieties under rainfed situation

S.No.	Varieties	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	T-9	9.7	8.8	9.3
2.	UPU-19	8.5	8.1	8.3
3.	P-1	10.2	8.8	9.5
4.	Mash-64	8.6	7.9	8.3
5.	Khargone	8.7	7.0	7.9
6.	Pant U-30	10.9	8.8	9.9
	CD at 5%	0.9	1.0	

Greengram : Among six green gram varieties tested under rainfed situation, Pusa Baisaki' recorded slightly higher yield than others but it remains at par with the variety T-1 having an average yield of 6.4 q/ha (Table 8).

Table - 8: Evaluation of green gram varieties under rainfed situation

S.No.	Varieties	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	T-1	6.1	6.7	6.4
2.	T-44	6.3	5.7	6.0
3.	Pusa Baisaki	6.7	6.5	6.6
4.	Jawahar-45	6.0	5.6	5.8
5.	Pant-1	6.1	5.7	5.9
6.	Pant-2	5.8	5.7	5.8
	CD at 5%	N.S.	0.5	

Soybean : Significantly higher average yield of 12.9 q/ha has been recorded by the soybean variety 'Ankur' followed by JS-2 (11.2 q/ha) as compared to other four varieties (Bragg, Gaurav, PK-416 and PK-327) those are found to be at par having an average yield of 10.4 q/ha (Table 9).

Table - 9: Evaluation of soybean varieties under rainfed situation

S.No.	Varieties	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	Ankur	10.2	13.7	12.9
2.	Bragg	9.0	12.8	10.9
3.	Gaurav	8.7	12.3	10.5
4.	PK-416	8.8	11.2	10.0
5.	PK-327	8.9	11.3	10.1
6.	JS-2	8.4	14.0	11.2
	CD at 5%	0.9	0.9	

Groundnut : Among six groundnut varieties tested, JL-24 recorded significantly highest average yield (10.3 q/ha) followed by 'Chandra' (9.2 q/ha) as compared to other four varieties (Chitra, Kausal, GG-11 and Joyti) those are found to be at par having an average yield of 7.7 q/ha (Table 10).

Table - 10: Evaluation of groundnut varieties under rainfed situation

S.No.	Varieties	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	Chitra	6.4	9.1	7.8
2.	Chandra	7.9	10.4	9.2
3.	JL-24	8.9	11.6	10.3
4.	Kaushal	5.8	8.8	7.3
5.	GG-11	6.3	9.8	8.0
6.	Jyoti	6.7	8.9	7.8
	CD at 5%	1.1	0.8	

Wheat : Results of evaluation of six wheat varieties under rainfed situation indicated that variety 'Mukta' is superior having an average yield of 21.4 q/ha followed by C-306, K-68 (19.4 q/ha) and K-8027, K-65 (17.4 q/ha) and lowest being 'Sonalika' having an average yield of 14.4 q/ha (Table 11).

Table - 11: Evaluation of wheat varieties under rainfed situation

S.No.	Varieties	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	Mukta	21.0	21.8	21.4
2.	K-65	14.3	20.0	17.2
3.	K-68	19.1	19.5	19.3
4.	K-8027	15.2	20.1	17.7
5.	C-306	16.5	22.5	19.5
6.	Sonalika	7.7	21.1	14.4
	CD at 5%	N.S.	1.3	

Gram : Evaluation of six gram varieties under rainfed situation revealed that T-3 and 'Radhey' yielded higher (15.4 q/ha) as compared to other varieties like T-87, K-458, K-850 and G-235 having an average yield level of 12 to 13 q/ha (Table 12).

Table - 12: Evaluation of gram varieties under rainfed situation

S.No.	Varieties	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	Radhey	13.9	16.1	15.0
2.	T-3	15.0	16.4	15.7
3.	T-87	13.1	14.7	13.9
4.	K-468	12.8	13.6	13.2
5.	K-850	12.9	11.3	12.1
6.	G-235	12.5	11.6	12.1
	CD at 5%	1.1	N.S.	

Pea : None of the six pea varieties tested for their yield performance showed significant difference, however, varieties 'Rachna' and 'Pant Matar-5' recorded higher yield 11.5 and 11.2 q/ha respectively (Table 13).

Table - 13: Evaluation of pea varieties under rainfed situation

S.No.	Varieties	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	Rachna	10.9	12.2	11.6
2.	T-163	9.9	10.8	10.4
3.	VL-Matar-1	10.0	10.3	10.2
4.	Pant Matar-5	10.0	12.3	11.2
5.	Malviya Matar-2	6.9	13.1	10.0
6.	L-116	9.7	9.5	9.7
	CD at 5%	N.S.	N.S.	

Mustard : Among six mustard varieties tested under rainfed situation 'Varuna' and 'Krishna' recorded significantly higher average yield of 11.3 q/ha followed by 'Vardan' (10.3 q/ha) and 'Kranti' (9.6 q/ha) whereas 'Vaibhav' registered the lowest yield of 5.8 q/ha (Table 14).

Table - 14: Evaluation of mustard varieties under rainfed situation

S.No.	Varieties	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	Varuna	9.0	13.6	11.3
2.	Krishna	10.4	12.1	11.3
3.	Pusabold	8.8	6.6	7.7
4.	Vardan	8.8	11.8	10.3
5.	Kranti	8.7	10.4	9.6
6.	Vaibhav	5.9	5.7	5.8
	CD at 5%	N.S.	5.3	

4.1.2 Intercropping studies

Results of two important intercropping studies, made on main crops like sorghum during *kharif* and gram during *rabi*, with an objective in minimising fluctuations in crop productivity, revealed that under rainfed situation, intercropping ensure and enchance crop productivity significantly to great extent as compared to pure cropping.

Studies on effect of intercropping with legumes on grain yield of sorghum during *kharif* indicated that intercropping of legumes resulted in 57.8 and 62.4 per cent higher yield in case of uniform (1:1) and paired (2:1) row, respectively as compared to sorghum (pure) yield of 16.4 q/ha (Table 15). Among four legumes tested for intercropping, soybean and black gram recorded higher yield followed by green gram and lowest with cowpea, in case of both main crop (Sorghum) as well as inter crop (legumes) yields (Table 16).

Similarly, during the rabi season, studies an intercropping were made to find out the effect of different intercrops on the grain yield of gram under rainfed situation revealed that paired row (2:1) increased yield by 16.7 per cent; whereas, 6.4 per cent in case of uniform row (1:1) as compared gram (pure) yield of 12.4

Table 15: Effect of intercropping of legumes on the grain yield of sorghum

Sl. No.	Treatment	Sorghum yield equivalent (q/ha)								
		Ist year			IInd year			Mean		
		MC	IC	Total	MC	IC	Total	MC	IC	Total
1.	Sorghum (UR) pure	13.1	-	13.1	20.1	-	20.1	16.6	-	16.6
2.	Sorghum (UR) + Cowpea (1:1)	10.7	8.1	18.8	16.3	10.6	26.9	13.5	9.4	22.9
3.	Sorghum (UR) + Soybean (1:1)	10.6	9.9	20.5	15.7	15.7	31.4	13.2	12.8	26.0
4.	Sorghum (UR) + Green gram (1:1)	10.6	11.8	22.4	16.1	11.5	26.6	13.4	11.7	25.1
5.	Sorghum (UR) + Black gram (1:1)	10.4	15.3	25.7	16.5	18.9	35.4	13.5	17.1	30.6
6.	Sorghum (PR) pure	12.8	-	12.8	19.5	-	19.5	16.2	-	16.2
7.	Sorghum (PR) + Cowpea (2:1)	10.5	10.6	21.1	16.6	9.6	26.2	13.6	10.1	23.7
8.	Sorghum (PR) + Soybean (2:1)	10.8	9.1	19.9	16.8	14.6	31.4	13.8	11.9	25.7
9.	Sorghum (PR) + Green gram (2:1)	10.6	10.9	21.5	16.9	12.9	29.8	13.3	11.9	25.2
10.	Sorghum (PR) + Black gram (2:1)	10.3	13.9	24.2	18.8	17.6	36.4	14.6	15.8	30.4
11.	Cowpea (UR) pure	-	21.3	21.3	-	28.9	28.9	-	25.1	25.1
12.	Soybean (UR) pure	-	18.7	18.7	-	28.8	28.8	-	23.8	23.8
13.	Green gram (UR) pure	-	16.2	16.2	-	19.2	19.2	-	17.7	17.7
14.	Black gram (UR) pure	-	25.3	25.3	-	27.3	27.3	-	26.3	26.3

UR = Uniform row PR = Paired row MC = Main crop IC = Inter crop

Selling rate (Rs. per quintal)

Sorghum : Rs. 350/- Cowpea : Rs. 1200/- Soybean : Rs. 1000/-

Green gram : Rs. 1300/- Black gram : Rs. 1400/-

Table 15: Effect of intercropping of legumes on the grain yield of sorghum

Sl. No.	Treatment	Sorghum yield equivalent (q/ha)								
		Ist year			IInd year			Mean		
		MC	IC	Total	MC	IC	Total	MC	IC	Total
1.	Sorghum (UR) pure	13.1	-	13.1	20.1	-	20.1	16.6	-	16.6
2.	Sorghum (UR) + Cowpea (1:1)	10.7	8.1	18.8	16.3	10.6	26.9	13.5	9.4	22.9
3.	Sorghum (UR) + Soybean (1:1)	10.6	9.9	20.5	15.7	15.7	31.4	13.2	12.8	26.0
4.	Sorghum (UR) + Green gram (1:1)	10.6	11.8	22.4	16.1	11.5	26.6	13.4	11.7	25.1
5.	Sorghum (UR) + Black gram (1:1)	10.4	15.3	25.7	16.5	18.9	35.4	13.5	17.1	30.6
6.	Sorghum (PR) pure	12.8	-	12.8	19.5	-	19.5	16.2	-	16.2
7.	Sorghum (PR) + Cowpea (2:1)	10.5	10.6	21.1	16.6	9.6	26.2	13.6	10.1	23.7
8.	Sorghum (PR) + Soybean (2:1)	10.8	9.1	19.9	16.8	14.6	31.4	13.8	11.9	25.7
9.	Sorghum (PR) + Green gram (2:1)	10.6	10.9	21.5	16.9	12.9	29.8	13.3	11.9	25.2
10.	Sorghum (PR) + Black gram (2:1)	10.3	13.9	24.2	18.8	17.6	36.4	14.6	15.8	30.4
11.	Cowpea (UR) pure	-	21.3	21.3	-	28.9	28.9	-	25.1	25.1
12.	Soybean (UR) pure	-	18.7	18.7	-	28.8	28.8	-	23.8	23.8
13.	Green gram (UR) pure	-	16.2	16.2	-	19.2	19.2	-	17.7	17.7
14.	Black gram (UR) pure	-	25.3	25.3	-	27.3	27.3	-	26.3	26.3

UR = Uniform row PR = Paired row MC = Main crop IC = Inter crop

Selling rate (Rs. per quintal)

Sorghum : Rs. 350/- Cowpea : Rs. 1200/- Soybean : Rs. 1000/-

Green gram : Rs. 1300/- Black gram : Rs. 1400/-

Table 16: Effect on intercropping of legumes on the yield of sorghum (q/ha)

Sl. No.	Treatment	Ist year		IInd year		Mean	
		MC	IC	MC	IC	MC	IC
1.	Sorghum (UR) pure	13.1	-	20.1	-	16.6	-
2.	Sorghum (UR) + Cowpea (1:1)	10.7	2.4	16.3	3.1	13.5	2.8
3.	Sorghum (UR) + Soybean (1:1)	10.6	3.5	15.7	5.5	13.2	4.5
4.	Sorghum (UR) + Green gram (1:1)	10.6	3.2	17.1	3.1	13.4	3.2
5.	Sorghum (UR) + Black gram (1:1)	10.4	3.8	16.5	4.7	13.5	4.3
6.	Sorghum (PR) pure	12.8	-	19.5	-	16.2	-
7.	Sorghum (PR) + Cowpea (2:1)	10.5	3.1	16.6	2.0	13.6	2.6
8.	Sorghum (PR) + Soybean (2:1)	10.8	3.2	16.8	5.1	13.8	4.2
9.	Sorghum (PR) + Green gram (2:1)	10.6	2.9	16.9	3.5	13.3	3.2
10.	Sorghum (PR) + Black gram (2:1)	10.3	3.5	16.8	4.4	14.6	4.0
11.	Cowpea (UR) pure	-	6.2	-	8.4	-	7.3
12.	Soybean (UR) pure	-	6.5	-	10.1	-	8.3
13.	Green gram (UR) pure	-	4.4	-	5.2	-	4.8
14.	Black gram (UR) pure	-	6.3	-	6.8	-	6.6
	C.D. at 5%	0.8	0.9	1.1	0.8	0.1	0.9

UR = Uniform row PR = Paired row MC = Main crop IC = Inter crop

Table 17: Effect of different intercrops on the yield of gram under rainfed situation

Sl. No.	Treatment	Gram yield equivalent (q/ha)								
		Ist year			IInd year			Mean		
		MC	IC	Total	MC	IC	Total	MC	IC	Total
1.	Gram (UR) pur	10.5	-	10.5	14.4	-	14.4	12.5	-	12.5
2.	Gram (UR) + Barley (1:1)	7.0	2.5	9.5	11.0	3.0	14.0	9.0	2.8	11.8
3.	Gram (UR) + Mustard (1:1)	6.7	3.4	10.1	10.8	4.5	15.3	8.8	3.9	12.7
4.	Gram (UR) + Linseed (1:1)	7.5	6.2	13.7	11.6	5.4	17.0	9.6	5.8	15.4
5.	Gram (PR) pure	10.2	-	10.2	14.6	-	14.6	12.4	-	12.4
6.	Gram (PR) + Barley (2:1)	6.6	2.2	8.8	12.6	2.6	15.2	9.6	2.4	12.0
7.	Gram (PR) + Mustard (2:1)	6.5	4.3	10.7	11.8	4.7	16.5	9.2	4.5	13.7
8.	Gram (PR) + Linseed (2:1)	6.9	6.6	13.5	12.0	7.0	19.0	9.5	6.8	16.3
9.	Barley (UR) pure	-	4.8	4.8	-	4.8	4.8	-	4.8	4.8
10.	Mustard (UR) pure	-	6.3	6.3	-	10.0	10.0	-	8.2	8.2
11.	Linseed (UR) pure	-	8.8	8.8	-	11.0	11.0	-	9.9	9.9

UR = Uniform row PR = Paired row MC = Main crop IC = Inter crop

Selling rate (Rs. per quintal)

Gram :Rs. 1200/- Barley : Rs. 550/- Mustard : Rs. 1200/- Linseed : Rs. 1800/-

Table 18: Effect of different intercrops on the yield of gram under rainfed situation (q/ha)

Sl. No.	Treatment	Ist year		IInd year		Mean	
		MC	IC	MC	IC	MC	IC
1.	Gram (UR) pure	10.5	-	14.4	-	12.5	-
2.	Gram (UR) + Barely (1:1)	7.0	5.5	11.0	6.6	9.0	6.1
3.	Gram (UR) + Mustard (1:1)	6.7	3.4	10.8	4.5	8.8	4.0
4.	Gram (UR) + Linseed (1:1)	7.5	4.1	11.6	3.6	9.6	5.6
5.	Gram (PR) pure	10.2	-	14.6	-	12.4	-
6.	Gram (PR) + Barely (2:1)	6.6	4.9	12.0	5.6	9.3	5.3
7.	Gram (PR) + Mustared (2:1)	6.5	4.3	11.8	4.7	9.2	4.5
8.	Gram (PR) + Linseed (2:1)	6.9	4.4	12.0	4.7	9.5	4.6
9.	Barely pure	-	10.4	-	10.5	-	10.5
10.	Musterd pure	-	6.3	-	9.8	-	8.1
11.	Linseed pure	-	5.9	-	7.9	-	6.9
	C.D. 5%	0.8	0.8	0.9	1.0	0.8	0.9

UR = Uniform row PR = Paired row MC = Main crop IC = Inter crop

q/ha (Table 17). Among three intercrops tested, linseed found to be most suitable followed by mustard and barley (Table 18) which recroded 15.9, 13.2 and 11.8 q/ha gram equivalent yield respectively (Table 17).

Present results regarding intercroping substantiate earlier observations (Narain *et al* 1980, Bonde and Mohan 1983, Hazra 1988, Narayana 1993) that under rainfed situation, combination of crops (intercropping) always found to be better than pure crop (single crop) not only in respect of productivity vis-a-vis monetary return but also for effective and continuous cover, thus facilitating reduction in soil erosion. Feeding of crops from different soil layers under intercropping system probably responsible for higher productivity (Hazra, 1988).

4.1.3 Sequential cropping

Results of the effect of *kharif* fodder crops on the grain yield of *rabi* crops indicated that keeping land fallow during *kharif* though marginally increased the *rabi* crops yield (Table 20) but declined average productivity per annum by 32 percent on the basis of the wheat yield equivalent (Table 20).

Table 19: Effect of kharif fodder crops on the grain yield of rabi crops (q/ha)

Kharif fodder Crops	Green fodder yield (q/ha)	Rabi crops				
		Gram	Mustard	Wheat	Barley	Mean
			Ist year			
Sorghum	263.7	15.8	10.3	23.5	17.5	16.8
Cowpea	224.1	15.7	11.7	22.2	18.9	17.1
Fallow	-	17.0	10.9	24.8	20.2	18.2
C.D. at 5%	-	0.5	0.5	0.9	1.8	0.5
			IInd year			
Sorghum	274.8	16.6	10.8	25.2	18.5	17.8
Cowpea	242.6	16.8	12.5	23.6	19.5	18.1
Fallow	-	17.9	12.0	26.8	21.3	19.5
C.D. at 5%	-	1.0	1.0	1.8	1.0	0.4
			Mean			
Sorghum	269.2	16.2	10.6	24.4	18.0	17.3
Cowpea	233.4	16.3	12.1	22.9	19.2	17.6
Fallow	-	17.5	11.5	25.8	20.8	18.9
C.D. at 5%	-	0.7	0.7	1.4	1.4	0.5

Table 20: Effect of sequential cropping of kharif fodders and rabi cropping of grain crops on total yield

Sl. No.	Crop rotation Kharif - Rabi	Wheat yield equivalent (q/ha) Ist year	IInd year	Mean
1.	Sorghum - Gram	53.6	56.6	55.0
2.	Sorghum - Mustard	40.6	42.4	41.5
3.	Sorghum - Wheat	39.3	41.7	40.5
4.	Sorghum - Barley	35.0	36.9	36.0
5.	Cowpea - Gram	51.1	54.9	53.0
6.	Cowpea - Mustard	41.7	44.6	43.2
7.	Cowpea - Wheat	35.7	38.2	36.9
8.	Cowpea - Barley	34.3	36.2	35.3
9.	Fallow - Gram	40.8	41.9	41.4
10.	Fallow - Mustard	26.2	27.5	26.9
11.	Fallow - Wheat	24.8	25.8	25.3
12.	Fallow - Barley	22.2	22.8	22.5

Among two *kharif* fodders, cowpea and sorghum, sequential cropping with cowpea as *kharif fodder* recorded marginally higher average grain yield of *rabi* crops, specially in case of mustard, as compared to *kharif fodder* sorghum based sequential cropping (Table 21). The average yield of mustard under

Table 21: Effect of kharif fodder crops on the grain yield of rabi crops as expressed in wheat yield euqivalent (q/ha)

Kharif Crops	Rabi Crops Gram	Mustard	Wheat	Barley	Mean
			Ist year		
Sorghum (15.8)	37.8	24.8	23.5	19.2	26.3
Cowpea (13.5)	37.6	28.2	22.2	20.8	27.2
Fallow -	40.8	26.2	24.8	22.2	28.5
			IInd year		
Sorghum (16.5)	39.8	25.9	25.2	20.4	27.8
Cowpea (14.6)	40.3	30.0	23.6	21.6	28.9
Fallow -	43.0	28.8	26.8	23.4	30.5
			Mean		
Sorghum (16.2)	38.8	25.4	24.4	19.8	27.1
Cowpea (14.0)	39.0	29.1	22.9	21.2	28.1
Fallow -	41.9	27.5	25.8	22.8	29.5

Figures in parentheses indicate kharif fodder yield expressed in equivalent wheat yield in (q/ha)

Selling rate (Rs. per quintal)

Sorghum (fodder) : Rs. 30/-	Gram : Rs. 1200/-	Barley : Rs. 550/-
Cowpea (fodder) : Rs. 30/-	Mustard : Rs. 1200/-	Wheat : Rs. 500/-

cowpea sequential croping increased by 14 percent over sorghum sequential cropping (Table 19, 21). Sorghum yielded 269.2 q/ha average green fodder which is 15 percent higher than that of the green fodder yield of cowpea (Table 19).

In terms of wheat yield equivalent (Table 20), sorghum/cowpea-gram rotation recorded maximum yield (54 q/ha) followed by sorghum/cowpea-mustard (42 q/ha), sorghum/ cowpea- wheat (38 q/ha) and lowest with sorghum/cowpea-barley (35 q/ha). Higher return under crop rotations involving kharif pulses and rabi pulses/oilseeds have also been reported earlier (Srivastava *et al* 1980, Agnihotri and Bhusan 1982, Subhas Chandra 1983),Nimje and Bhatdarkar 1990) in case of rainfed farming.

4.1.4 Tillage practices

Results of effect of tillage practices on sorghum grain yield under rainfed situation (Table 22) revealed that different shallow (upto 10 cm depth) tillage practices like deshi ploughing, blade harrowing, bullock drawn disc harrowing alone and combination of deshi ploughing along with disc harrowing, failed to show any significant effect on yield of sorghum which recorded an average yield of 8.9 q/ha. On the other hand, deeper (more than 25 cm and upto 60 cm depth) tillage practices like chisel ploughing followed by disc harrowing or sub-soiler followed by disc harrowing are found to be statistically at par with tillage practice like tractor drawn mould board ploughing (depth varies between 22.5 to 25 cm) showing an average yield of 14.5 q/ha. Thus results of present investigation confirmed that deep tillage practices having depth between 20 to 25 cm like tractor drawn disc harrowing or tractor drawn mould board ploughing are optimum (12.9 q/ha) so far sorghum grain yield is concerned. Neither shallow tillage (upto 10 cm depth) nor deeper tillage (depth more than 25 cm) practices found suitable economically.

The efficacy of deep tillage in conserving moisture in profile and makes it available to the plant roots, thereby increasing the moisture use efficiency for increased production of maize, pearl millet, toria, wheat as compared to shallow tillage has been reported by several workers (Bhusan *et. al.* 1977, Singh and Verma 1994, Suraj Bhan 1996). However, shallow tillage practice in between cropped rows, specially in vertisols, proved to be efficient as an intercultural operations in enhancing rainfed crop yields of wheat, safflower, linseed and chickpea (Sharma and Gupta 1990) through enhanced water use efficiency that results from reduction in evaporation loss of soil moisture.

Table 22: Effect of tillage practices on sorghum grain yield (q/ha)

Sl. No.	Treatment	Soil working cm	Ist year	IInd year	Mean
1.	*Deshi* plaughing	7.5-10.0	9.5	9.0	9.3
2.	Blade harrowing	5.0-7.5	7.7	8.5	8.1
3.	Bullock drawn disc harrowing	5.0-7.5	8.6	9.0	8.8
4.	*Deshi* ploughing + Disc harrowing	7.5-10.0	10.5	8.3	9.4
5.	Tractar drawn Disc harrowing	20.0-22.5	12.0	12.0	12.0
6.	Tractar drawn mould Board ploughing	22.5-25.0	13.8	13.8	13.8
7.	Chisel ploughing followed by Disc harrowing	45.0-50.0	14.5	14.6	14.6
8.	Sub-soiler followed by Disc harrowing	50.0-60.0	15.3	15.6	15.5
	CD at 5%		1.2	3.7	2.5

4.1.5 Fertilizer use studies

Results of the effect of split application of nitrogen on the productivity (grain yield) of sorghum with the recommended level (80 kg N/ha) revealed that application of nitrogen as 50 per cent basal alongwith two equal splits (25% each) at 25 and 45 days after sowing resulted in maximum average yield of 22.0 q/ha (Table 23) followed by combination (75% basal +25% at 45 DAS) having yield of 20 q/ha. Grain yield of sorghum reduced further to the level of 18 q/ha which is found to be statistically at par with 100 per cent basal application, when nitrogen applied as single split (along with corresponding amount as basal) either 25% at 25 DAS or 50% at 25 DAS or 50% at 45 DAS. Optimum vegetative and root growth of sorghum due to better availability of applied nitrogen under two equal splits along with basal, probably remain responsible for higher yield. The study conclusively establishes the benefit of split nitrogen application to the rainfed sorghum crop than a full basal application.

Table 23: Split application of nitrogen to rainfed sorghum grain yield

Sl. No.	Method of application	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	100% basal	16.0	17.1	16.6
2.	75% basal + 25% at 25 DAS	17.0	18.2	17.6
3.	75% basal + 25% at 45 DAS	20.2	20.0	20.1
4.	50% basal + 50% at 25 DAS	18.0	18.2	18.1
5.	50% basal + 50% at 45 DAS	17.3	19.1	18.2
6.	50% basal + 25% at 25 DAS + 25% at 45 DAS	21.0	23.1	22.0
	CD at 5%	1.21	1.11	1.16

DAS = *days after sowing*

4.1.6 Mulching studies

Mulching increased yield of mustard significantly during first yiear of experimentation (1985-86) but failed to show its effect during 1986-87 (2nd year) probably because of dry spell prevailing upon between August through Feburary as evident from the rainfall distribution data of Tejpura watrshed (Table 1). Rainfall distribution during August, September and October determines the efficacy of mulching in subsequent rabi crops. All the three mulch material (dry grass, sorghum stover and rice husk) tested found to be equally effective and superior than that of soil mulch (Table 24). Usefulness of mulching for better water conservation and yield increment has been also reported earlier (Singh *et. al.* 1967, Dakshinamurti 1972, Singh and Bhusan 1978, Hazra 1988).

Table 24: Effect of mulching on yield of mustard

Sl. No.	Treatment	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	No Mulching	11.1	10.2	10.6
2.	Soil mulching (3-4 cm)	12.0	10.1	11.0
3.	Dry grass @ 5t/ha	14.3	14.0	14.2
4.	Sorghum stover @ 5t/ha	14.0	14.0	14.0
5.	Rice husk @ 5t/ha	14.1	11.1	12.6
	CD at 5%	0.42	N.S	

Ist year 1985-86;
IInd year 1986-87

4.1.7 Single supplemental irrigation

One supplemental irrigation increased yield of all the four crops tested (sorghum, pigeonpea, groundnut and soybean) significantly as compared to non irrigated crops. Increase in per cent yield found to be varied between 49 in groundnut and 54 in soybean leading to an average increase of 52 per cent due to application of single supplemental irrigation of 75 mm (Table 25).

The increase in yield increases progressively with the increase in the quantity of applied irrigation water (Table 26). An increase in yield of 17, 36 and 57 per cent has been recorded against application of 25, 50 and 75 mm irrigation water, respectively over control (no irrigation). Present observations alongwith similar findings earlier (Rao *et. al.* 1981, Singh 1983, Hazra 1988) points towards the fact that single supplemental irrigation not only saves the crops from virtual withering during dry spell but also helps in increasing production particularly under dryland agriculture.

Table 25: Effect of single supplemental irrigation on yields of kharif crops

Level of irrigations (mm)	kharif crops (grain yields in q/ha)				
	Sorghum	Pigeon pea	Groundnut	Soybean	Mean
	Ist year				
No irrigation	12.2	6.6	14.1	10.1	10.7
25	13.9	8.0	16.5	12.1	12.7
50	16.1	9.3	19.1	14.3	14.7
75	18.9	10.7	20.9	16.1	16.7
C.D. at 5%	0.3	0.3	0.3	0.3	0.3
	IInd year				
No irrigation	13.7	7.8	14.0	11.3	11.7
25	14.9	8.5	17.2	12.8	13.4
50	16.9	10.0	20.0	15.9	15.7
75	20.0	11.1	21.1	16.9	17.3
C.D. at 5%	0.3	0.3	0.3	0.3	0.3
	Mean				
No irrigation	13.0	7.2	14.1	10.7	11.2
25	14.4	8.3	16.9	12.5	13.1
50	16.5	9.7	19.6	15.1	15.2
75	19.5	10.9	21.0	16.5	17.0
C.D. at 5%	0.3	0.3	0.3	0.3	0.3

Table 26: Effect of single supplemental irrigation on yields of sorghum, pigeon pea, soyabean and groundnut

Treatment	Grain Sorghum equivalent yield(q/ha)		
	Ist year	IInd year	Mean
Crops			
Sorghum	15.3	16.4	15.9
Pigeon pea	12.4	13.4	12.9
Groundnut	61.2	61.9	61.6
Soyabean	37.6	40.7	39.2
Level of Irrigations (mm)			
No irrigation	24.7	26.3	25.5
25	29.2	30.6	29.9
50	33.9	35.5	34.7
75	38.0	41.4	39.7

Selling rate (Rs. per quintal)

Sorghum : Rs. 350/-
Pigeon pea : Rs. 1050/-
Groundnut : Rs. 1200/-
Soybean : Rs. 1000/-

4.2 Crop production and management under irrigated condition

4.2.1 Crop rotations

Results of interaction between important crop rotations and fertility levels, under irrigated condition, revealed that application of full (100%) recommended doses of fertilizers in *kharif* as well as in *rabi* season enhanced the yield of both *kharif* and *rabi* crops (Table 27). Reduction in fertility level by half (50%) during *kharif* only reduced *kharif, rabi* and annual yield by 24, 8 and 14 per cent, respectively. Similarly, 50 per cent reduction in fertility level during *rabi* only reduced *rabi* and annual yield by 24 and 15 per cent, respectively as compared to 100 per cent fertiliity level both in *kharif* and *rabi* seasons (Table 28).

In terms of equivalent wheat yield, groundnut-wheat rotation recorded highest yield (111 q/ha) followed by sorghum-gram rotation (77 q/ha) and sorghum-wheat rotation (66 q/ha) as evident from the data presented in table 28.

Sorghum and groundnut yield found to be reduced by 28 and 20 per cent, respectively when recommended fertilizer dose reduced to half. Similarly, reduction in recommended fertilizer doses by half during *rabi,* reduced both gram and wheat yield by 20 per cent under sorghum- wheat and sorghum-gram rotations. However, reduction in wheat yield under groundnut-wheat rotation found to be higher (32%) indicating thereby exhaustive nature of groundut crop in extracting palnt nutrients as compared to sorghum (Table 27).

Table 27: Effect of fertility levels to various crop rotations on crop yield (q/ha)

Fertility levels	Crop rotations					
	Sorghum -	Wheat	Sorghum -	Gram	Groundnut -	Wheat
50% K + 100% R	15.5	32.6	14.9	16.0	14.6	32.3
100% K + 50% R	21.3	27.5	20.4	14.1	18.3	26.0
100% K + 100% R	20.9	34.7	20.5	17.5	18.6	39.4
C.D. at 5%	0.9	3.8	0.9	3.8	0.9	3.8
50% K + 100% R	16.4	34.2	15.7	17.2	15.5	38.3
100% K + 50% R	23.1	29.5	22.0	15.5	19.7	27.7
100% K + 100% R	22.6	36.1	23.0	19.8	19.6	40.5
C.D. at 5%	0.6	3.5	0.6	3.5	0.6	3.5
50% K + 100% R	16.0	33.4	15.3	16.6	15.1	35.3
100% K + 50% R	22.4	28.5	21.2	14.8	19.0	26.8
100% K + 100% R	21.8	35.4	21.8	18.6	19.1	39.9
C.D. at 5%	0.8	3.7	0.8	3.7	0.8	3.7

K= *Kharif* R= *Rabi*

Table 28: Effect of fertility levels to various crop rotations on yields expressed as equivalent wheat yield (q/ha)

Treatment	Ist year			IInd year			Mean		
	K	R	Total	K	R	Total	K	R	Total
Crop rotation									
Sorghum-Wheat	19.2	45.2	64.4	20.7	47.5	68.2	20.0	46.4	66.4
Sorghum-Gram	18.6	54.5	75.1	20.2	59.9	80.1	19.4	57.2	76.6
Groundnut - Wheat	58.8	48.8	107.7	62.7	50.7	113.4	60.8	49.8	110.6
Fertility levels									
50% K + 100% R	26.8	51.6	78.4	28.4	54.2	82.6	27.6	52.9	80.5
100% K + 50% R	34.8	41.6	76.4	37.6	44.9	82.5	36.2	43.3	79.5
100% K + 100%R	35.0	55.3	90.3	37.6	59.1	96.7	36.3	57.2	93.5

K = Khari R = Rabi

Selling rate (Rs. per quintal)

Groundnut : Rs. 1200/- Gram Rs. 1200/- Wheat : Rs. 500/-

4.2.2 Fertilizer studies

Response of different level of phosphorus and sulphur fertilization in four crops (gram, mustard, groundut and soybean) at Tejpura watershed showed a significant positive and additive interactions.

Gram : Average yield response fo gram towards P-fertilization found to be slightly higher than that of S-fertilization (Table 29). Application of 20 and 40 kg/ha phosphorus alone, increase gram yield by 21 and 29 per cent, respectively; whereas, same level of sulphur fertilization alone, increase gram yield by 13 per cent as compared to control (without P and S fertilization) yield of 12.8 q/ha. Application of 60 kg P and 40 kg S/ha recorded highest average yield of 20.9 q/ha (Table 30).

Mustard: Average yield response of mustard towards S-fertilization found to be slightly higher than that of P-fertilization (Table 31). Application of 20 and 40 kg/ha sulphur alone, increase mustard yield by 34 and 58 per cent, respectively; whereas, same level of phosphorus fertilization alone increases mustard yield by 27 and 46 per cent respectively as compared to control (without P and S fertilization) yield of 9.2 q/ha. Application of 40 kg P and 60 kg S/ha recorded highest average yield of 17.5 q/ha (Table 32).

Groundnut : Average yield response of groundnut towards P-fertilization found to be slightly higher than that of S-fertilization (Table 33). Application of both P and S @ 60 kg/ha yielded significantly highest yield of 24.2 q/ha as compared to control (without P and S fertilization) yield of 13.1 q/ha (Table 34).

Table 29: Effect of phosphorus and sulphur on gram yield (q/ha)

Treatment	Ist year	IInd year	Mean
P-Levels (Kg/ha)			
0	13.8	13.9	13.9
20	15.9	16.5	16.2
40	17.0	17.6	17.3
60	19.4	19.4	19.2
CD at 5%	0.2	0.5	0.4
S-Levels (Kg/ha)			
0	15.4	15.8	15.6
20	16.7	17.2	17.0
40	17.3	17.6	17.5
CD at 5%	0.2	0.4	0.3
Interaction	0.4	0.9	0.7

Table 30: Interaction of phosphorus and sulphur on gram yield (q/ha)

P-levels (kg/ha)	Ist year S-levels (kg/ha)			IInd year S-levels (kg/ha)			Mean S-levels (kg/ha)		
	0	20	40	0	20	40	0	20	40
0	13.0	14.3	14.0	12.6	14.6	14.7	12.8	14.5	14.4
20	14.6	16.1	16.9	16.4	16.6	16.6	15.5	16.4	16.8
40	16.2	17.1	17.7	16.8	17.8	18.2	16.5	17.5	18.0
60	17.9	19.4	20.8	17.4	19.9	21.0	17.7	19.7	20.9

Table 31 : Effect of phosphorus and sulphur on mustard yield (q/ha)

Treatment	Ist year	IInd year	Mean
P-Levels (Kg/ha)			
0	12.5	15.0	13.8
20	14.0	14.4	14.2
40	15.2	15.9	15.5
CD at 5%	0.3	0.2	0.3
S-Levels (Kg/ha)			
0	11.3	11.5	11.4
20	13.5	14.2	13.9
40	15.0	15.4	15.2
60	15.7	16.5	16.1
CD at 5%	0.6	0.2	0.4
Interaction	0.8	0.4	0.6

Table 32: Interaction of phosphorus and sulphur on mustard yield (q/ha)

S-levels (kg/ha)	Ist year P-levels (kg/ha)			IInd year P-levels (kg/ha)			Mean P-levels (kg/ha)		
	0	20	40	0	20	40	0	20	40
0	9.1	11.7	13.2	9.2	11.6	13.6	9.2	11.7	13.4
20	11.8	13.8	15.0	12.8	14.3	15.4	12.3	14.1	15.2
40	14.4	15.1	15.7	14.6	15.3	16.2	14.5	15.2	16.0
60	14.7	15.4	16.9	15.4	16.1	18.1	15.1	15.8	17.5

Table 33: Effect of Phosphorus and sulphur on groundnut yield (q/ha)

Treatment	Ist year	IInd year	Mean
P-Levels (Kg/ha)			
0	14.0	14.4	14.2
20	16.6	16.7	16.6
40	20.1	20.0	20.0
60	21.1	21.4	21.3
CD at 5%	0.3	0.4	0.4
S-Levels (Kg/ha)			
0	15.5	15.6	15.6
20	17.5	17.6	17.6
40	19.2	19.7	19.5
60	19.6	19.6	19.6
CD at 5%	0.8	0.4	0.6
Interaction	0.6	0.8	0.7

Table 34: Interation of phosphorus and sulphur on groundnut yield (q/ha)

S-levels	Ist year				IInd year				Mean			
(kg/ha)	P-levels (kg/ha)				P-levels (kg/ha)				P-levels (kg/ha)			
	0	20	40	60	0	20	40	60	0	20	40	60
0	12.6	14.8	16.6	17.7	13.5	14.4	16.6	18.1	13.1	14.6	16.6	17.9
20	14.1	16.8	19.1	19.9	14.2	17.3	19.0	20.0	14.2	17.1	19.1	20.0
40	14.8	17.8	21.9	22.4	15.1	18.2	22.1	23.6	15.0	18.0	21.0	23.0
60	14.5	16.8	22.7	24.4	14.7	17.1	22.5	24.0	14.6	17.0	22.6	24.2

Soybean : Average yield response of soybean towards P-fertilization found to be slightly higher than that of S-fertilization (Table 35). Application of both P and S @ 60 kg/ha recorded significantly highest yield of 19 q/ha as compared to control (without P and S fertilization) yield of 9.7 q/ha (Table 36). However, application of S-fertilization alone, above 20 kg/ha found to be insignificant.

Results of another study regarding fertilizer use at Tejpura watershed indicate an increase in yields of crops ranged from 54-71, 91-150 and 118-200 per cent in case of fertilizer applications of 50, 75 and 100 per cent recommended level of fertilizer, respectively. Highest increase was noted with wheat and lowest with sorghum (Table 37).

Table 35: Effect of phosphorus and sulphur on soybean yield (q/ha)

Treatment	Ist year	IInd year	Mean
P-Levels (Kg/ha)			
0	10.3	10.5	10.4
20	13.2	13.1	13.2
40	15.4	15.5	15.5
60	16.6	17.3	17.0
CD at 5%	0.3	0.2	0.3
S-Levels (Kg/ha)			
0	12.5	13.0	12.8
20	13.6	14.0	13.8
40	14.4	14.5	14.5
60	15.1	14.8	15.00
CD at 5%	0.3	0.2	0.3
Interaction	0.5	0.5	0.5

Table 36: Interaction of phosphorus and sulphur on soybean yield (q/ha)

S-levels (kg/ha)	Ist year P-levels (kg/ha)				IInd year P-levels (kg/ha)				Mean P-levels (kg/ha)			
	0	20	40	60	0	20	40	60	0	20	40	60
0	9.6	11.7	14.0	14.9	9.8	11.7	14.6	16.1	9.7	11.7	14.3	15.5
20	10.4	13.4	15.0	15.7	10.6	13.6	15.6	16.5	10.5	13.5	15.3	16.1
40	10.4	14.1	16.1	17.1	11.0	13.6	15.9	17.6	10.7	14.4	16.0	17.4
60	10.9	13.7	16.7	18.9	10.7	13.5	15.9	19.1	10.8	13.6	16.3	19.0

Table 37: Effect of fertiliser nutrients on yields of some selected crops of Tejpura watershed

Treatment*	Yield (q/ha) Wheat	Gram	Sorghum	Groundnut
No fertiliser nutrient (control)	14.2	9.3	11.0	10.2
100% recommended dose	42.0(200)	21.2(133)	24.1(118)	25.0(150)
75% recommended dose	35.2(150)	18.1(100)	21.2(91)	21.2(110)
50% recommended dose	24.0(71)	14.1(56)	17.3(54)	16.2(60)

* *Fertilisation dose applied to wheat and sorghum @ 80 kg N and 40 kg* P2O5/ha, gram 20 kg N and 40 kg P2O5 and groundnut 20 kg N, 60 kg P2O5 and 40 kg K_2O/ha

Figures in paranthesis indicates per cent increase in yield over control.

4.2.3 Fertiliser nutrient use scenario

Initially, the consumption of fertiliser was very meagre and was only restricted to the irrigated area of about 20.2 ha specially under the wheat crop. No other crops were fertilised and raised only on organic manures like FYM. Total nutrient use was of the order of 808 kg N and 404 kg P_2O_5 in the total cropped area of 436.8 ha initially (1982-83). Nutirent consumption was of the order of 1.85 and 0.92 kg/ha for N and P_2O_5, respectively (Table 38). Watershed treatment was completed in the year 1985-86. With the increased water resources development and creation of enough irrigation potentiality, the land use and the cropping practices greatly changed over the years. During 1990-91, the total consumption of fertiliser nutrients were of the order of 40590, 24645 and 2400 kg of N, P_2O_5 and K_2O respectively in the entire watershed which would otherwise meant that 62.2, 37.7 and 3.7 kg/ha for the respective nutrients. This increase in use of fertiliser is due to increased cropped area from 436.8 ha to 652.5 ha and increased cropping intensity, 206 per cent from initial 82 percent (Table 50).

Table 38: Use of fertiliser nutrients (N,P_2O_5, K_2O and S) to crops over the years at Tejpura watershed

Year	Actual cropped area (ha)	Total fertiliser nutrient use in the watershed (kg)				Total nutrients (N,P_2O_5, K_2O and S) use (kg/ha)
		N	P_2O_5	K_2O	S	
1982-83	436.80	808 (1.85)	404 (0.92)	0	0	2.77
1990-91	652.50	40590 (62.20)	24645 (37.70)	2400 (3.70)	0	103.60

Figure in paranthesis indicates fertiliser nutrient consumption as kg/ha.

4.2.4 Irrigation studies

Results of irrigation water management at different growth stages of wheat (Table 39) revealed that one irrigation at CRI stage increased wheat yield by 27 per cent as compared to no-irrigation (15.5 q/ha). Second irrigation at tillering or boot or flowering stage found to be equally effective and increased wheat yield by 27 per cent over single irrigation at CRI stage (19.7 q/ha). Third irrigation at boot stage or flowering stage found to be equally effective in increasing wheat yield significantly by 20 per cent over two irrigations at CRI and

tillering stage (25 q/ha). However, third irrigation at milk stage or grain formation stage failed to increase wheat yield significantly over two irrigations at CRI and tillering stage. Fourth irrigation at flowering stage significantly increase wheat yield (35.6 q/ha) by 18 per cent over three irrigations at CRI, tillering and boot stage (30 q/ha). Fifth irrigation at milk stage failed to increase wheat yield significantly further (36.5 q/ha). However, sixth irrigation at grain formation stage significantly increased wheat yield (39.9 q/ha) by 9 per cent over five irrigations (36.5 q/ha).

Table - 39: Effect of irrigation at different growth stages of wheat on yield

Sl. No.	Treatment	No. of irrigation	Grain yield (q/ha)		
			Ist year	IInd year	Mean
1.	No irrigation (I_0)	0	14.4	16.2	15.5
2.	One irrigation at crown root initiation stage (I_1)	1	18.6	20.8	19.7
3.	I_1 + One irrigation at tillering stage(I_2)	2	22.9	26.7	24.8
4.	I_1 + One irrigation at boot stage (I_3)	2	23.2	25.9	24.6
5.	I_1 + One irrigation at flowering stage (I_4)	2	24.2	27.0	25.6
6.	I_2 + One irrigation at boot stage (I_5)	3	28.3	30.7	29.5
7.	I_2 + One irrigation at flowering stage (I_6)	3	29.4	31.8	30.6
8.	I_2 + One irrigation at milk stage (I_7)	3	30.0	22.6	26.3
9.	I_2 + One irrigation at grain formation stage (I_8)	3	29.5	24.1	26.8
10.	I_5 + One irrigation at flowering stage (I_9)	4	33.8	37.4	35.6
11.	I_9 + One irrigation at milk stage (I_{10})	5	33.8	39.1	36.5
12.	I_{10} + one irrigation at grain formation stage (I_{11})	6	36.7	43.1	39.9
	CD at 5%		1.7	1.9	1.8

Wheat yield found to be increased progressively with the increase in the number of irrigations. As compared to wheat yield without any irrigation (15.5 q/ha), first irrigation at CRI stage yielded 19.7 q/ha (+27%), 2nd irrigation at tillering stage yielded 24.8 q/ha (+60%), 3rd irrigation at boot stage yielded 29.5 q/ha (+90%), 4th irrigation at Howering stage yielded 35.6 q/ha (+130%), 5th irrigation at milk stage yielded 36.6 q/ha (+135%) and 6th irrigation at grain formation stage yielded 39.9 q/ha (+157%).

Supplemental irrigation studies were made to different crops from 1985-86 to 1988-89. Data presented in (Table 40) revealed that yield increases of 54-72 per cent were observed with single supplemental irrigation (average irrigation of 50 mm) to various crops, whereas, two irrigations resulted in yield increases of the order 90-109 per cent over no irrigation. Subsequent third and fourth irrigations in wheat increases yield further to the level of 138 and 162 per cent, respectively. Similar results have been reported earlier too (Singh 1983, Grewal and Juneja 1986, Singh 1990).

Table 40: Effect of supplemental irrigation on yields of some selected crops at Tejpura watershed

Number of irrigation	Yield (q/ha)			
	Wheat	Gram	Sorghum	Groundnut
No irrigation	16.1	10.2	11.0	11.2
One irrigation	25.0 (56)	16.2 (60)	17.2 (54)	19.1(72)
Two irrigation	32.2(100)	19.0 (90)	22.2(100)	23.0(109)
Three irrigation	38.0(138)	-	-	-
Four irrigation	42.1(162)	-	-	-

Figures in paranthesis indicates per cent yield increase over no irrigation

4.2.5 Component study

Contribution of different production components, alone and in combination, towards enhancement of sorghum and wheat productivity has been studied and results are being presented in Table 41 and 42, respectively.

Sorghum : Improved variety only increased yield level from 10.5 to 14.1 q/ha (+34%) following farmer's practices which increased further to the level of 20 q/ha (+42%) under improved package of practices.

Improved package of practices increased yield of farmer's variety from 10.5 to 13.9 q/ha (+32%) and improved variety from 14.1 to 20 q/ha (+42%) as compared to farmer's practices.

Improved package practices and improved variety together increased yield from 10.5 q/ha to 20 q/ha (+90%) which increased further to the level of 22.6 q/ha (+13%) with one irrigation.

Wheat : Improved variety only increased yield level from 17.4 to 27.3 q/ha (+57%) following farmer's practices which increased further to the level of 33.7 q/ha (+23%) under improved package of practices.

Improved package of practices increased yield of farmer's variety from 17.4 to 26.7 q/ha (+53%) and improved variety from 27.3 to 33.7 q/ha (+23%) as compared to farmer's practices.

Table 41: Effect of improved practices on sorghum yield

Sl. No.	Treatment	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	Farmer's variety + Farmer's practices	10.1	10.9	10.5
2.	Improved variety + Farmer's practices	13.7	14.4	14.1
3.	Farmer's variety + Improved package of practices	13.6	14.2	13.9
4.	Improved variety + Improved package of practices	19.5	20.5	20.0
5.	Farmer's variety + Farmer's practices + one irrigation	12.8	13.4	13.1
6.	Improved variety + Improved package of practices + one irrigation	21.9	23.2	22.6
	CD at 5%	1.8	1.9	1.8

Improved package practices and improved variety together increased yield from 17.4 to 33.7 q/ha (+94%) which increased further to the level of 39.1 q/ha (+16%) with two irrigations.

Three components, namely improved variety, improved package of practices and increased irrigation level (3 to 5 numbers) contributed significantly in enhancing wheat yield by 57, 53, and 15, per cent respectively (Table 42). All the three components together brought an overall change in wheat yield from 17.4 to 39.1 q/ha (+125%).

Table 42: Effect of improved practices on wheat yield

Sl. No.	Treatment	Grain yield (q/ha)		
		Ist year	IInd year	Mean
1.	Farmer's variety + Farmer's practices + 3 irrigation	17.0	17.9	17.4
2.	Improved variety + Farmer's practices + 3 irrigation	26.5	28.0	27.3
3.	Farmer's variety + Improved package of practices + 3 irrigation	26.8	26.6	26.7
4.	Improved variety + Improved package of practices + 3 irrigation	32.8	34.7	33.7
5.	Farmer's variety + improved package of practices + 5 irrigation	28.1	28.5	28.3
6.	Improved variety + improved package of practices + 5 irrigation	38.4	39.7	39.1
	CD at 5%	1.6	1.8	1.7

4.2.6 Studies on soil and water conservation measures

The entire watershed area was treated with appropriate soil and water conservation measures (Table 43). The soil conservation work included ocntour bunding (23.3 ha) and field bunding to the extent possible on contour alignment (558.9 ha). Diversion channel of 1657 metre long had been constructed to guide high velocity run-off from hills and hillocks to the *nallahs* (Seasonal stream). The gully plugging was done to the extent of 64.4 ha area and 70 *pucca* drainage structures were constructed for the safe disposal of excess water from field to fields. Two underground irrigation channels were constructed and 4.6 ha area was levelled.

Table 43: Soil and water conservation measures adopted at Tejpura watershed

Works	Achievement
Contour bunding (ha)	23.28
Submergence-cum-field bunding (ha)	558.94
Land levelling (ha)	4.60
Gully plugging (ha)	64.38
Diversion channel (m)	1657.00
Drainage structure (No.)	70.00
Underground irrigation channel (No.)	2.00
Total cost on soil and water conservation (Rs./ha) (On the basis of 1985-86)	2342.00
Total cost on soil and water conservation (Rs./ha) (cost as of 1995-96) *	6065.00

** On discounted basis*

4.2.6.1 Effect of bunding

Studies on bunding were taken up for two normall rainfall season of 1985-86 and 1987-88 and one drought year of 1986-87. The yield data presented in (Table 44) indicated that bunded plots helped quite significantly in yield increases of the crops to the extent of 40-80 per cent during normal years and by 87-225 per cent duirng drought year over the non-bunded field. It is quite intersting to note that highest yield increase was noted with sorghum during normal years and with groundut during drought season.

4.2.6.2 Effect of levelling

During the early phases of the watershed treatment studies were made from 1985-86 to 1987-88 to study the effect of levelling as a component of soil and water conservation activity on the yield and economics of different crops. Data presented in (Table 45) indicated that the yield of different crops increased by 50-115 per cent due to levelling over non-levelled plots. Highest such increase was noted with groundnut. Additional incomes from levelling were ranged from Rs. 2400/- to Rs. 9000/- with lowest benefit from sorghum and highest from groundnut.

Table 44: Effect of contour bunding/field bunding on crop yeilds during normal and drought year at Tejpura watershed

Treatment	Yield (q/ha)			
	Wheat	Gram	Sorghum	Groundnut
Normal year: (2)				
No bunding	25.0	12.2	10.2	14.0
Bunding	35.2	17.1	18.3	20.3
Per cent increase in yield due to bunding	40	42	80	43
Drought year: (1)				
No bunding 15.1	6.2	7.0	4.1	
Bunding	28.2	13.0	15.1	13.2
Per cent increase in yield due to bunding	87	116	114	225

Table 45: Effect of levelling on yield of some selected crops at Tejpura watershed

Treatment	Yield (q/ha)			
	Wheat	Gram	Sorghum	Groundnut
Non levelling	26.0	11.2	11.2	8.0
Levelling	40.2	17.3	19.3	18.1
Increase in yield due to levelling (%)	50.0	54.0	73.0	115.0
Additional cost (Rs/ha)	4800.0	4500.0	4500.0	5300.0
Additional income (Rs/ha/yr)	5600.0	5400.0	2400.0	9000.0

Results of the study on the effect of soil and water conservcation measures in relation to the varieties of traditional vis-a-vis improved ones and improved methods of cultivation practices (that includes fertilizer as well as irrigation besides others package of practices) on important crops like sorghum, wheat, groundnut and gram are being presented below.

Table 46: Effect of soil and water conservation measures alongwith improved package of practices on yield of sorghum crop (q/ha)

Sl. No.	Treatment	Ist Year	IInd Year	Mean
(A)	**Soil and Water Conservation measures**			
1.	Without soil and water conservation measures (outside watershed area)	14.6	15.2	14.9
2.	With Soil and Water conservation measures (within watershed area)	16.5	18.8	17.6
	CD at 5%	0.7	0.6	0.6
(B)	**Improved package of practices**			
1.	Traditional varieties with traditional practices	10.8	11.2	11.0
2.	Improved variety with traditional practices	15.9	16.5	16.2
3.	Traditional varieties with improved practices	16.6	17.7	17.2
4.	Improved varieties with improved practices	20.1	22.2	21.2
	CD at 5%	0.9	0.9	0.9

Sorghum : Soil and water conservation measures alone increased average sorghum yield form 14.9 to 17.6 q/ha (+18%) which increased further to the level of 21.2 q/ha (+20%) through improved variety and package of practices (Table 46). Soil and Water conservation measures alongwith improved varieties and package of practices increased sorghum yield by 92 per cent as compared to traditional method of cultivation outside watershed area having an average yield level of 11.0 q/ha.

Wheat: Soil and water conservation measures alone increased average wheat yield from 26.3 to 27.6 q/ha (+5%) which increased further to the level of 36.4 q/ha (+32%) through improved varieties and package of practices (Table 47). Soil and water conservation measures alongwith improved variety and package of practices increased wheat yield by 77 per cent as compared to traditional method of cultivation outside watershed area having an average yield level of 20.6 q/ha.

Table 47: Effect of soil and water conservation measures alongwith improved package of practices on yield of wheat crop (q/ha)

Sl. No.	Treatment	Ist Year	IInd Year	Mean
(A)	**Soil and Water Conservation Measures**			
1.	Without Soil and Water conservation measures (outside watershed area)	25.3	27.2	26.3
2.	With Soil and Water conservation measures (within watershed area)	26.4	28.9	27.6
	C.D. at 5%	0.6	0.9	0.8
(B)	**Improved package of practices**			
1.	Traditional varieties with traditional practices	19.8	21.5	20.6
2.	Improved variety with traditional practices	23.0	25.8	24.4
3.	Traditional varieties with improved practices	25.4	27.3	26.4
4.	Improved varieties with improved practices	35.0	37.8	36.4
	CD at 5%	0.9	1.2	1.1

Groundnut : Soil and water conservation measures alone increased average groundnut yield from 13.5 to 16.7 q/ha (+24%) which increased further to the level of 20.6 q/ha (+23%) through improved varieties and package of practices (Table 48). Soil and water conservation measures alongwith improved variety and package of practices increased groundnut yield by 100 per cent as compared to traditional method of cultivation outside watershed area having an average yield level of 10.3 q/ha.

Table 48: Effect of soil and water conservation measures alongwith improved package of practices on yield of groundnut crop (q/ha)

Sl. No.	Treatment	Ist Year	IInd Year	Mean
(A)	**Soil and Water Conservation Measures**			
1.	Without Soil and Water conservation measures (outside watershed area)	13.9	13.0	13.5
2.	With Soil and Water conservation measures (within watershed area)	17.2	16.1	16.7
	CD at 5%	0.5	0.5	0.5
(B)	**Improved package of practices**			
1.	Traditional varieties with traditional practices	10.5	10.0	10.3
2.	Improved variety with traditional practices	15.2	14.3	14.8
3.	Traditional varieties with improved practices	14.9	14.4	14.7
4.	Improved varieties with improved practices	21.6	19.6	20.6
	CD at 5%	0.6	0.8	0.7

Gram : Soil and water conservation measures alone increased average gram yield form 15.0 to 16.9 q/ha (+13%) which increased further to the level of 20.4% q/ha (+21%) through improved varieties and package of practices (Table 49). Soil and water conservation measures alongwith improved variety and package of practices increasd gram yield by 58 per cent as compared to traditional method of cultivation outside watershed area having an average yield level of 12.9 q/ha.

Table 49: Effect of soil and water conservation measures alongwith improved package of practices on yield of gram crop (q/ha)

Sl. No.	Treatment	Ist Year	IInd Year	Mean
(A)	**Soil and Water Conservation Measures**			
1.	Without Soil and Water conservation measures (outside watershed area)	15.4	14.7	15.0
2.	With Soil and Water conservation measures (within watershed area)	16.6	17.1	16.9
	CD at 5%	0.6	0.5	0.5
(B)	**Improved package of practices**			
1.	Traditional varieties with traditional practices	13.0	12.8	12.9
2.	Improved variety with traditional practices	16.9	15.6	16.2
3.	Traditional varieties with improved practices	16.7	15.9	16.3
4.	Improved varieties with improved practices	21.4	19.3	20.4
	CD at 5%	0.8	0.7	0.8

4.3 Water resource development

The basic irrigation potentiality was limited to 20.2 ha of area in the watershed which was about 3.8 per cent of then cropped area. The irrigation was available through 5 functional wells and 7 wells were non-functional. The construction of 4 check dams in the *nallah* helped in a great way in storing excess rain water in the form of run-off for the purpose of irrigation to crops (Table 50). Each structure has a capacity of 3 hectare metre (ha m) of water except for the first one with a capacity of 4 ha m. In addition to the one constructed during 1991-92 at the upper reach by joining two hillocks at 350 m apart has a cpacity of 10 ha m. Thus, the water available for irrigation from these check dams was to the tune of 23 ha m. In addition to these, three gully plugs

helped about storing 1 ha m of water additionally during rainy season. The total water thus, available from these conservation structures was estimated to be 24 ha m.

4.3.1 Dug-out wells

The number of wells which were initially 5 rose to 35 during 1985-86, 112 during 1988-89 and 167 by end of 1991-92 (Table 50). All these resulted in achieving cropping intensity of 206 per cent from initial level of 82 per cent and 92 per cent area was brought under irrigation from basic level of only 3.8 per cent (Table 50). Irrigation resources development had greatly helped in bringing about 651 ha land under protective irrigation cover during *rabi* season and if need be similar areas during *kharif* season (Table 50). The irrigation water availability from the wells also helped in getting about 65 ha area under third crop (Table 50).

The rise in impounded rain water in check dams and *in-situ* water conservation through increased infiltration and storage in individual field helped due to field bunding resulted in the recharge of ground water in a significant way. Data on status of ground water table is presented in Table 50. This indicates that the groundwater level varied from 3-6 m over the seasons during 1991-92 having an average water table depth of 4.2 m, whereas the initial ground water table fluctuation was between 6-14.6 m having an average water table depth of 10.9 m. This indicated a rise of underground water level by 3-8.6 m over the years.

4.3.2 Land use pattern

With the implementation of soil and water conservation measures, an additional area of 126 hectare wasteland/degraded land has been brought under cultivation which constitute about 22 per cent of the present cultivated area of 652.5 ha (Table 50). The entire cultivated area was brought under improved crop production technology after the adoption of soil and water conservation measures. The land utilisation pattern in terms of irrigated and rainfed areas after the completion of the soil and water conservation work was also greatly changed (Table 50). The irrigated area was changed from a meagre 20.2 ha to 603 ha, which accounts for about 92 per cent of total cultivated area.

Table - 50: Water resource development through implementation of soil and water conservation measures and its influence on land use pattern and cropping intensity at Tejpura watershed

Items	Before watershed (1982-83)	After watershed (1985-86)	After 3 years (1988-89)	After 6 years (1991-92)
Water resource development				
No of open wells	5	35	112	167
Command area/well (ha)	105	18.6	5.8	3.9
No. of check dams	nil	4	4	5
Water Storage in check dams (ha m)	nil	12	13	23
Irrigated area (%)	3.8	69	83	92
Average water table depth (m)				
- Summer	14.6	6.5	8.5	6.0
- Rainy	6.0	2.5	4.0	3.0
- Winter	12.0	3.5	6.0	3.5
- Annual (average)	10.9	4.2	6.2	4.2
- Maximum fluctuation	8.6	4.0	4.5	3.0
Land use pattern				
Total area (ha)	775.7	775.7	775.7	775.7
cultivated area (ha)				
- irrigated	20.2	449.5	541.5	603.0
- rainfed	505.4	202.0	110.5	49.5
- total	525.6	651.5	652.0	652.5
Area under crops (ha)				
- kharif	116	365	525	630
- rabi	321	637	651	651
- summer	nil	15	48	65
- fallow 89 nil nil nil				
Degraded and area under miscellaneous uses (ha)	250	124	124	124
Degrated/wastelands brought under cultivation (ha)	nil	126	126	126
Cropping intensity (%)	82	156	188	206

The watershed treatment was completed in 1985-86

Fig. 4 : Gully embankment stabilization through vegetative measures

Fig. 5 : Complete gully plugging

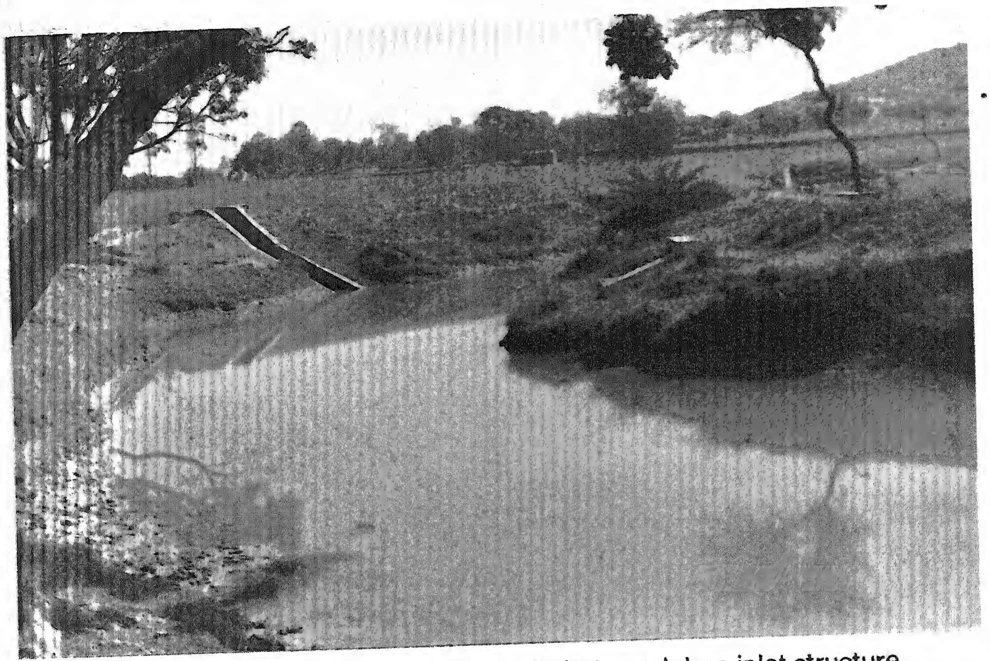


Fig. 6 : Gully head control - view of chute and drop inlet structure

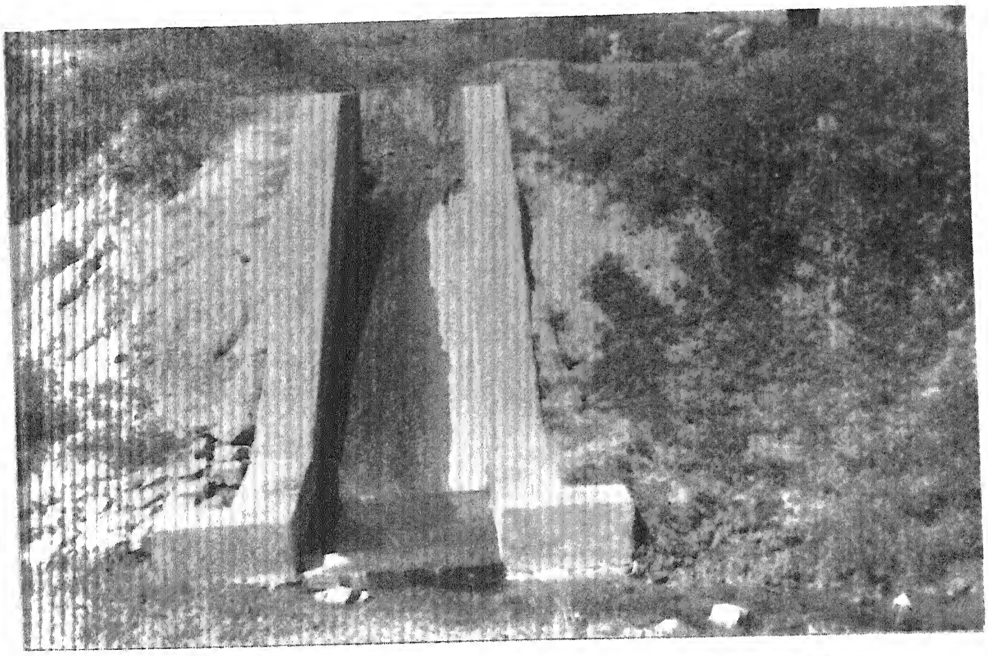


Fig. 7 : Chute structure for water disposal from fields

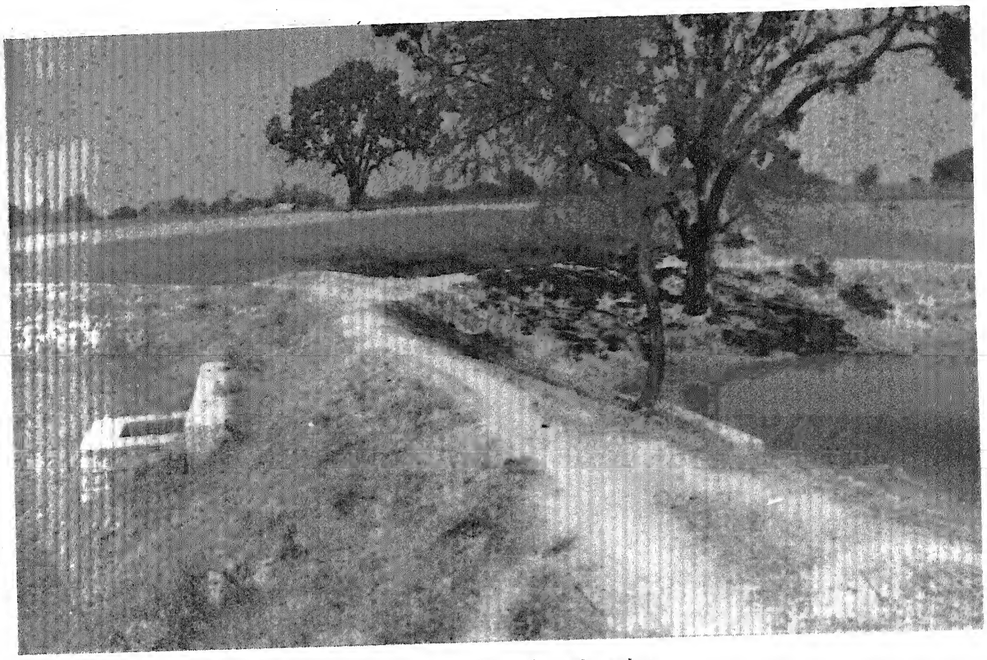


Fig. 8 : Drop inlet structure

Fig. 9 : Earthen check - dam - a low cost technology

Fig. 14 : Exposed tree roots showing extent of soil erosion - stabilized after watershed intervention

Fig. 15 : Vetiver grasses for the stabilization of bunds

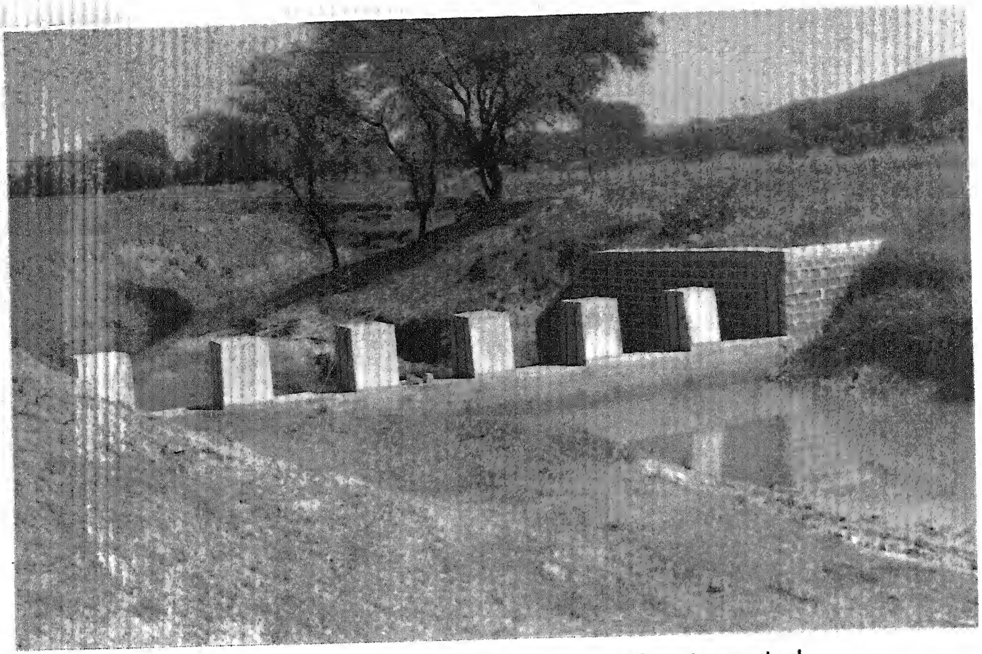


Fig. 10 : A low cost check-dam with gate control

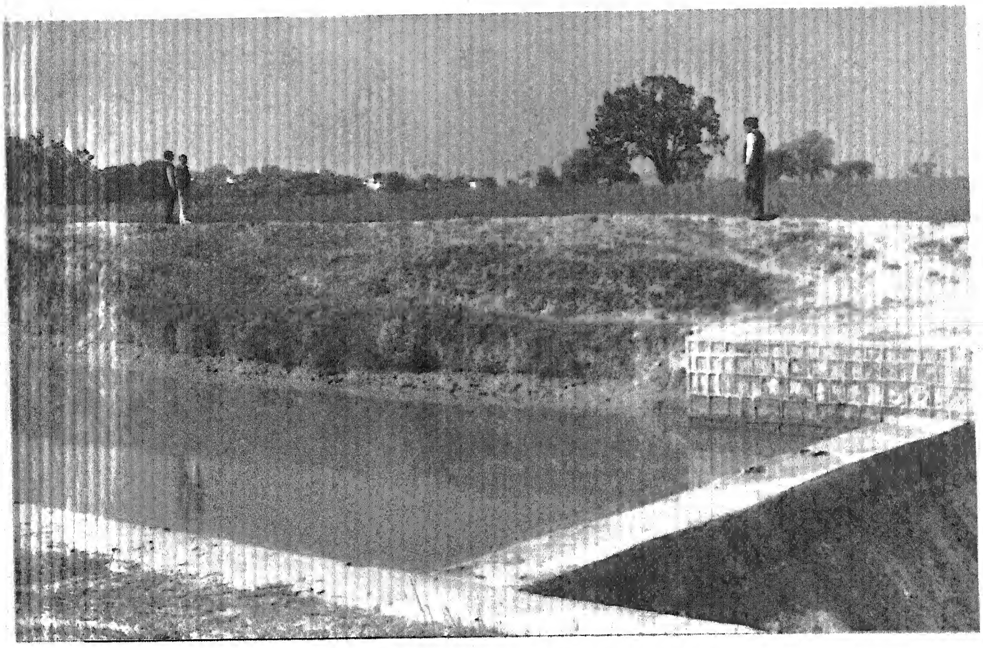


Fig. 11 : Check-dam on ani-cuts

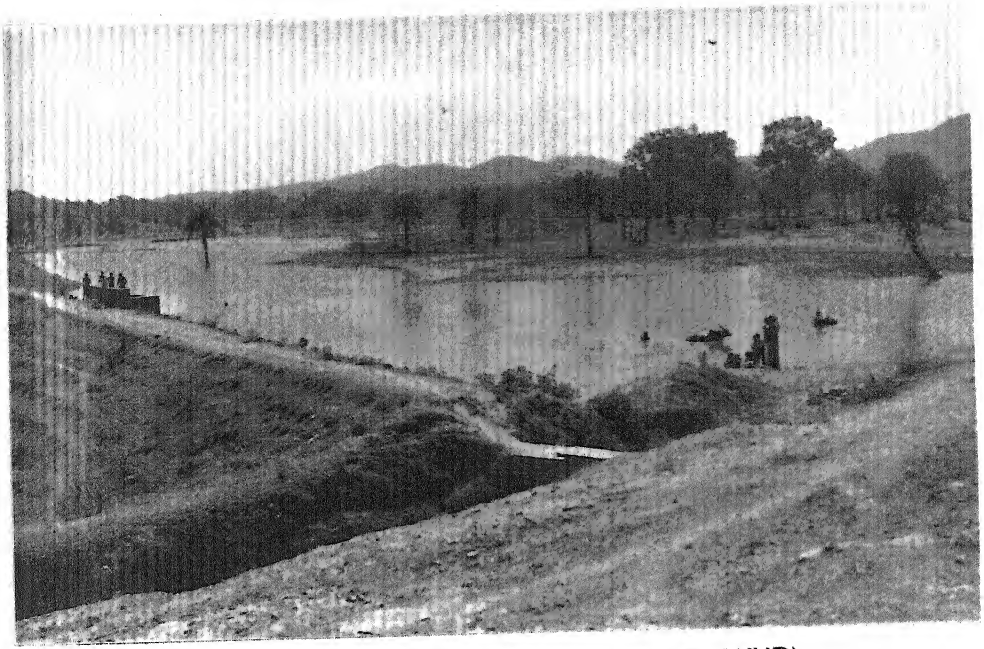


Fig. 12 : Check-dam for water harvesting (WHD)

Fig. 13 : Water harvesting structure - depecting emergency outlet

Fig. 14 : Exposed tree roots showing extent of soil erosion - stabilized after watershed intervention

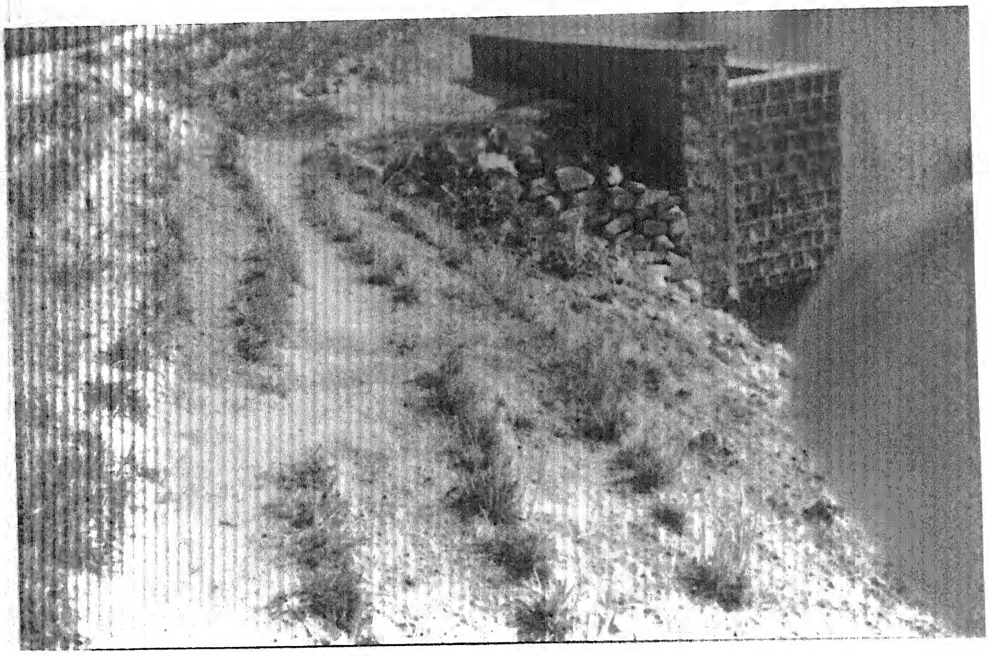


Fig. 15 : Vetiver grasses for the stabilization of bunds

4.3.3 Productivity of crops

Of 775.7 hectare land in the watershed, only 525.6 ha area was initially fit for cultivation. Actual cropping was limited to 436.8 ha area and amongst these, 116 ha was with *kharif* cropping and 321 ha was under *rabi* cropping. The scenario changed considerably with the completion of soil and water conservation work during 1985-92. About 126 ha degraded land was reclaimed for cultivation. An area of 630 ha during *kharif*, 650 ha during *rabi* and 65 ha during *zaid* were put to cropping during 1991-92. These resulted in marked rise in the productivity of different crops. The productivity of different *kharif* crops was increased from 110 to 300 per cent and 120 to 344 in case of *rabi* crops (Table 51) over the basic yield levels. Much higher yield was observed with wheat (344%) followed by sesamum and mustard (both 300%). It was observed that the cropped area of groundnut was increased in the spectacular way from 1 ha initially to 172 ha, alomost 30 per cent of *kharif* cropped area. Two new crops namely, soybean and cowpea has been introduced besides vegetables. It was observed that the vegetables cultivation specially tomato in about 37 ha in *rabi* season and 60 ha in *zaid* season came in a big way during 1991-92 (Table 51).

Annual crop production of the watershed found to be raised to 5800 kg/ha from a meagre 600 kg/ha that is an increase by about 10 times which has also been reflected in the gross annual income (Rs./family/yr) by 9 times over initial levels of Rs. 240 per month (Table 52).

4.4 Pasture development and afforestation

4.4.1 Fertility studies

Study involving use of fertilizer to rangeland grasses, improved pastures and silvipasture, it was noted that the addition of fertilizers @ 40 kg N and 40 kg P_2O_5/ha greatly helped the biomass production (Table 53), the increse in forage yields after seven years of study were of the order or 20, 42 and 52 per cent with the application of fertiliisers over no fertilisation in case of natural rangelands, improved pasture and silvipasture, respectively. Similarly is the trend in crude protein yield. Crude protein yield increases were of the order of 39-65 per cent due to fertilisation.

Table 51 : Change in area and average productivity of principal crops as influenced by watershed management at Tejpura.

Crops	Before watershed (1982-83) Area (ha)	Before watershed (1982-83) Productivity (q/ha)	After watershed (1991-92) Area (ha)	After watershed (1991-92) Productivity (q/ha)	Increase in Productivity (%)
Kharif (rainy)					
Sorghum	105.5	6.0	342	17.0	183
Black gram	7.0	3.2	20	7.5	134
Green gram	0.5	3.0	37	6.3	110
Cowpea	nil	nil	5	7.0	New
Sesamum	1.0	1.0	26	4.0	300
Soyabean	nil	nil	8	15.0	New
Groundnut	1.0	5.0	172	19.0	280
Paddy	2.3	10.5	20	40.1	282
Rabi (winter)					
Wheat	210.2	9.0	405	40.0	344
Chickpea	86.4	6.0	160	19.0	217
Barley	5.0	7.5	9	16.5	120
Mustard	15.0	3.0	36	12.0	300
Linseed	0.5	4.0	2	12.5	213
Lentil	1.5	4.5	2	10.5	133
Vegetables (peas, tomato Potato)	2.0	70.0	37	175.0	150
Zaid (Summer)					
Vegetables (Colocasia, Onion, ladies finger, brinjal, bottle gourd)	nil	nil	60	150.0	New
Green gram	nil	nil	5	7.0	New

The watershed treatment was completed in 1985-86

Table 52: Productivity of crops and annual gross income over the years at Tejpura watershed

Period	Average yields (kg/ha)			Average annual production from hectare land (kgs)	Average income per hectare (Rupees)	Annual income per family (Rupees)
	Kharif	Rabi	Zaid			
1983-84 (base year)	500	780	-	600	1670	2900
1985-86 (Completion year for soil and water conservation	1060	3150	5250	3790	10550	18200
1988-89 (after three year from completion)	1920	3950	6560	5500	14320	24600
1990-91 (after five years from completion)	2050	4100	8500	5800	15100	26500

Table 53: Effect of fertilisation on the productivity of pastures and silvipastures at Tejpura watershed

Vegetation/ Fertilisation	Dry forage yield (q/ha)		Crude protein yield (kg/ha)	
	After one year	After seven years	After one year	After seven years
Natural randelands* (Protected from grazing)				
Without fertilisation	10.2	36.1	50.50	165.6
With fertilisation	30.5	43.5	147.80	235.0
Improved pastures *(Cenchrus Cliaris + Stylosanthes hamata)*				
Without fertilisation	28.9	50.2	259.0	492.0
With fertilisation	38.8	71.5	335.0	638.5
Silvipasture *(Cenchrus Cliaris + Stylosanthes hamata* Leucaena leuconcephala)				
Without fertilisation	39.0	62.5	328.0	590.5
With fertilisation	52.5	95.0	440.5	972.0

* *Vegetational composition of natural range lands were Aristida, Eremopogon foveolaths, Heterpogon contortus etc.*

Fig. 16 : Digging of open wells - a bright crop prospect

Fig. 17 : A good wheat crop benefited by irrigation resource development

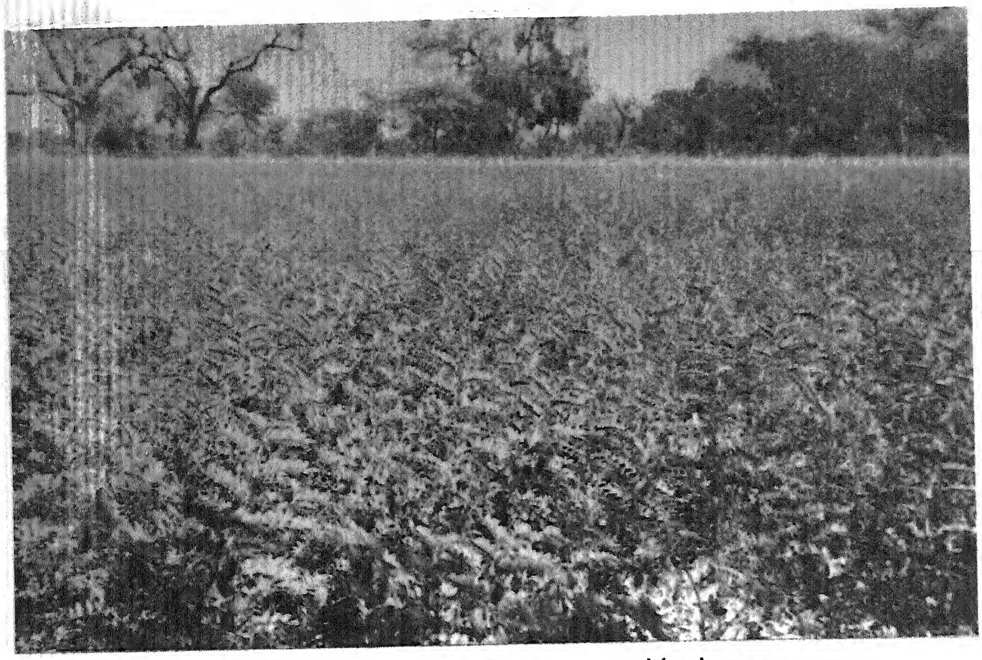


Fig. 18 : Gram - most important *rabi* pulse crop

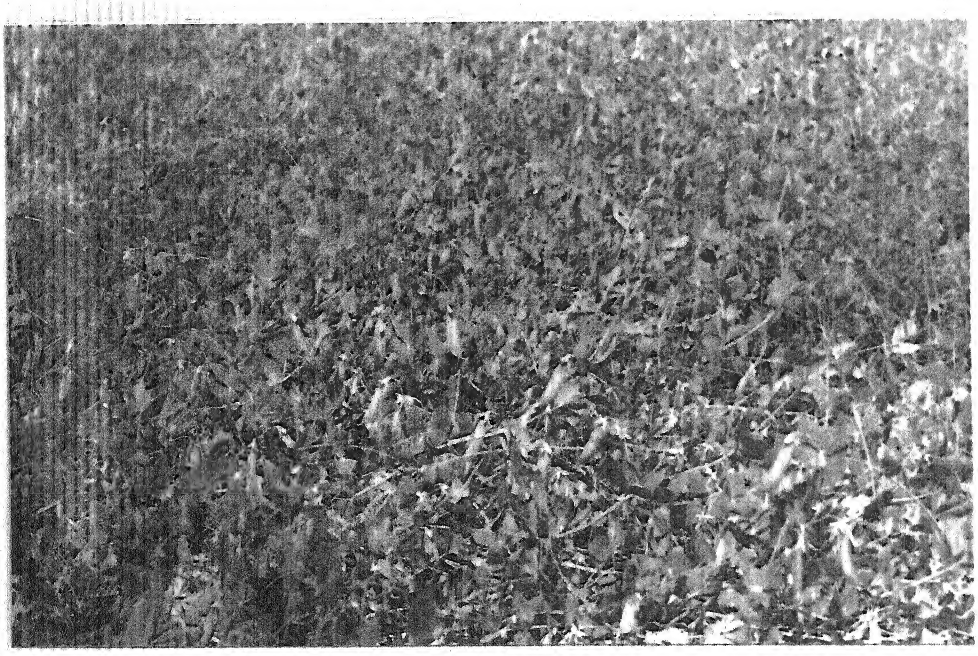


Fig. 19 : Pea - important vegetable crop for *rabi* season

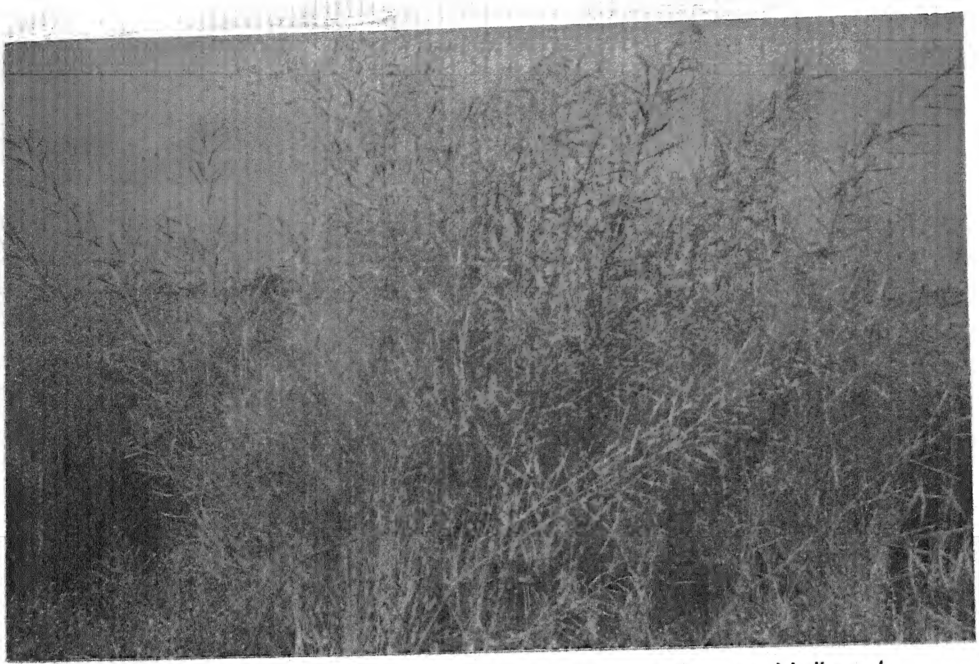


Fig. 20 : A productive mustard crop - an important *rabi* oilseed

Fig. 21 : A good pigeonpea crop on field bund source of additional income

Fig. 22 : Sorghum - an important traditional *kharif* crop

Fig. 23 : Demonstration of improved varieties of sorghum

Fig. 24 : A good newly introduced groundnut crop having plump shells

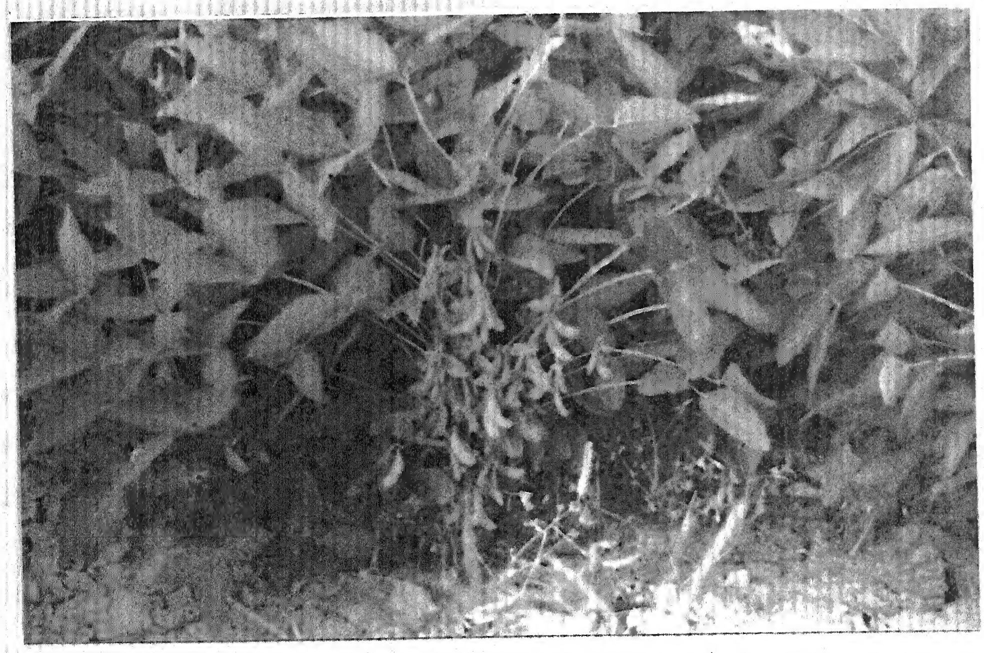


Fig. 25 : Soybean - successfully introduced new crop

4.4.2 Succession of grasses

Evaluation of effect of protection as well as soil and water conservation measures, on ecological succession of range grasses and legumes, after five years, revealed that there was luxuriant growth of many species of forage grasses, simply through natural regeneration (Table 54) which contributed significantly in increasing forage yield (Table 56). Among regenerated species, *Dicanthium annulatum* and *Bothrichloa intermedia* found to be most dominant, followed by *Apluda mutica, Thermada* sp., *Digitaria* sp., *Cenchrus* sp., *Sehima nervosum* and *chrysopagon fulvus* (Table 54).

Table 54: Effect of protection and soil and water conservation measures on ecological succession of range grasses and legumes after five years.

Grass and legume sp. before any protection and treatment	Proportion of species (%)	Grass and legume sp. after five years of protection and soil and water conservation treatment adoption	Proportion of species (%)
Aristida sp. (*Aristida mutabilis, A. funiculata, A. adscensionis*)	35	*Dicanthium annulatum*	18
		Bothrichloa intermedia	12
		Heteropogon contortus	8
		Apluda mutica	8
Eremopogon foveolatus	18	*Themada* sp.	8
Heteropogon contortus	15	*Digitaria* sp.	7
Indigofera cordifolia	3	*Cenchrus* sp.	7
		Sehima nervosum	7
		Chrysopagon fulvus	5
Other annual grasses	30	Others (*Indigofera cordifolia, Atylosia scaraboides,* Annual grasses)	20

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		Sehima nervosum	7
		Chrysopagon fulvus	5
Other annual grasses	30	Others (*Indigofera cordifolia, Atylosia scaraboides,* Annual grasses)	20

4.4.3 Regeneration of trees & shrubs

Tremendous regeneration of trees and shrubs species has been observed within five years in the community grazingland at the watershed owing to protection from human and livestock interferences only (Table 55). Most dominant regenerating species found to be *Butea monosperma* followed by *Acacia leucocephala, Anognissus pendula, zizphus zuzuba* and *Logastroemia perviflora.*

Table 55: Regeneration of trees and shrubs after five years in the community grazingland at the watershed

Name of the species	Number per hectare	
	Before watershed treatment	After watershed treatment
Acacia leucocephala	2	138
Butea monosperma	32	605
Anoguissus pendula	13	162
Ziziphus zuzuba	3	38
Carrisa karonda	8	68
Logastroemia parviflora	-	32

4.4.4 Survival of trees and pasture production

Studies were undertaken on the revegetated hills and data on forage yield from pasture on five years average basis in Table 56 indicated that the average productivity of grasses were increased by 29 times. As the length of slope of the hills decreased, the producxtivity of pasture increased. Survival of trees were also quite high in the foot hills (88%) followed by hills slopes (75%) and low survival rate at hill tops (38%). Canopy coverage by trees also followed the similar ways to that of survival percentage. Infiltrated photosynthetically active radiation (PAR) was also very low in lower slope with only 19 per cent as against 92 per cent on hill top.

Table 56: Effect of soil and water conservation measures on forage yield, survival of afforested plants on hills and hillocks at Tejpura watershed

Land situation	Dry forage (q/ha)		Survival per cent of trees after five years	Per cent canopy coverage after five years	Photosynthetically active radiation* (PAR) ($\mu EM^{-2} sec^{-1}$)	Relative radiation to open (%)
	Before watershed development	After five years of treatment				
Hill top	0.70	41.0	38	23	1408	92
Hill slope	1.30	59.5	75	85	610	39
Foot hills	3.80	71.2	88	92	285	19
Mean	1.90	57.2	67	67	768	50

* *Open radiation 1530 $\mu E\ m^{-2}\ sec^{-1}$*

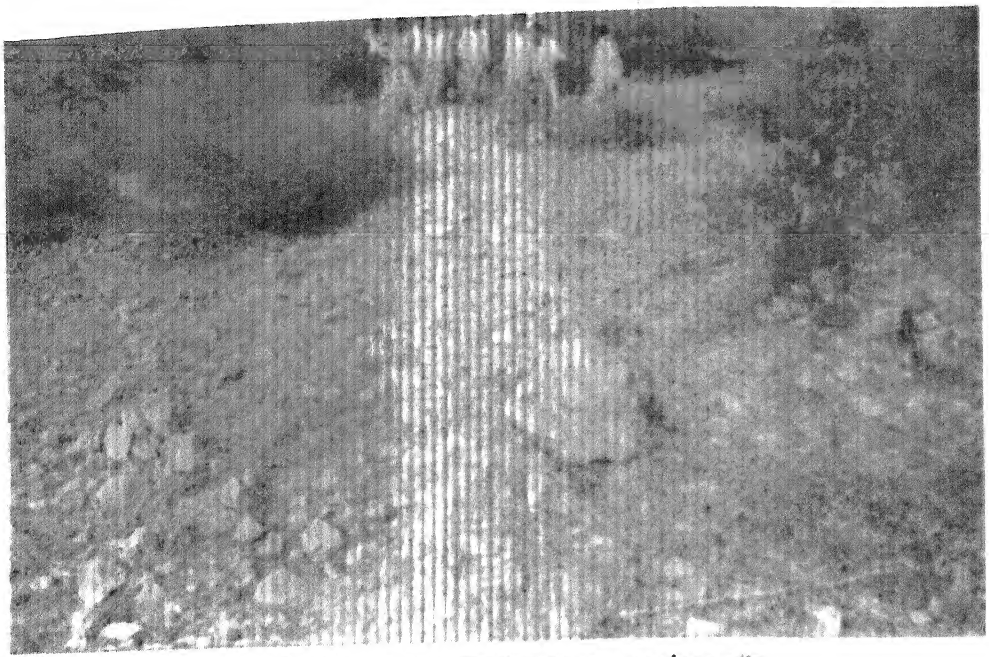


Fig. 26 : Footthills affected by scree deposits

Fig. 27 : Regeneration of hills - haulted scree deposits - a productive wheat crop

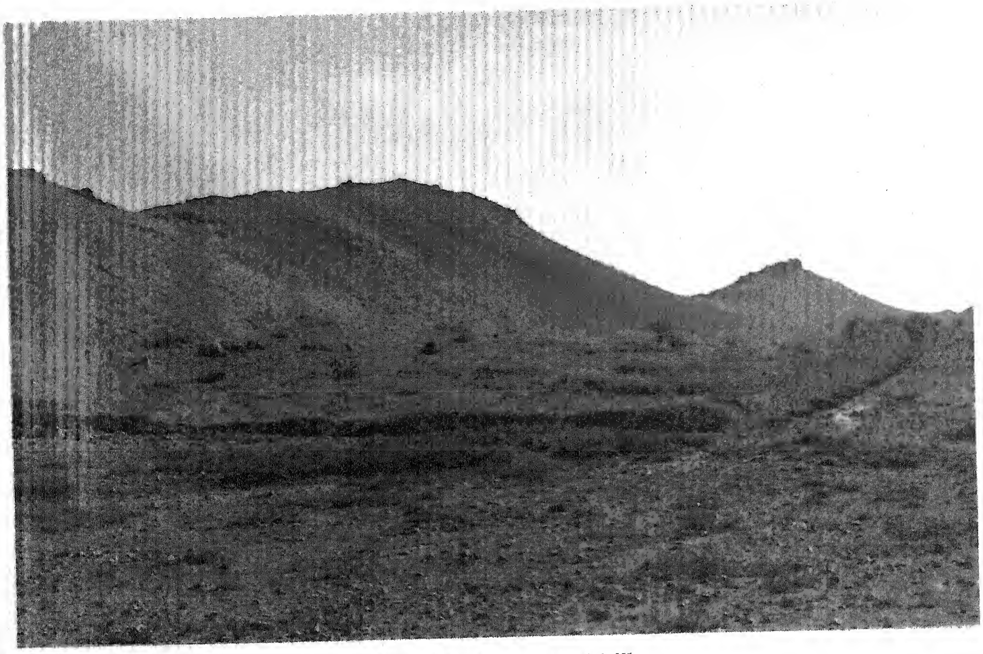


Fig. 28 : Degraded hills

Fig. 29 : Regeneration of hills

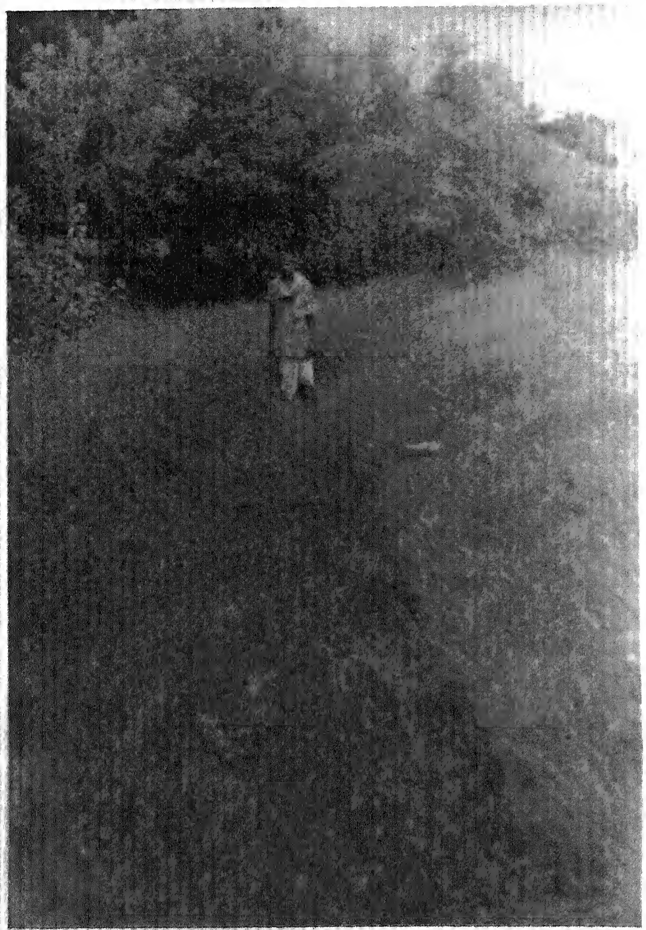


Fig. 30 : Pasture development

Fig. 31 : Regenerated hills - *Anoguissus pendula* the most important regenerating species of Vindhyans

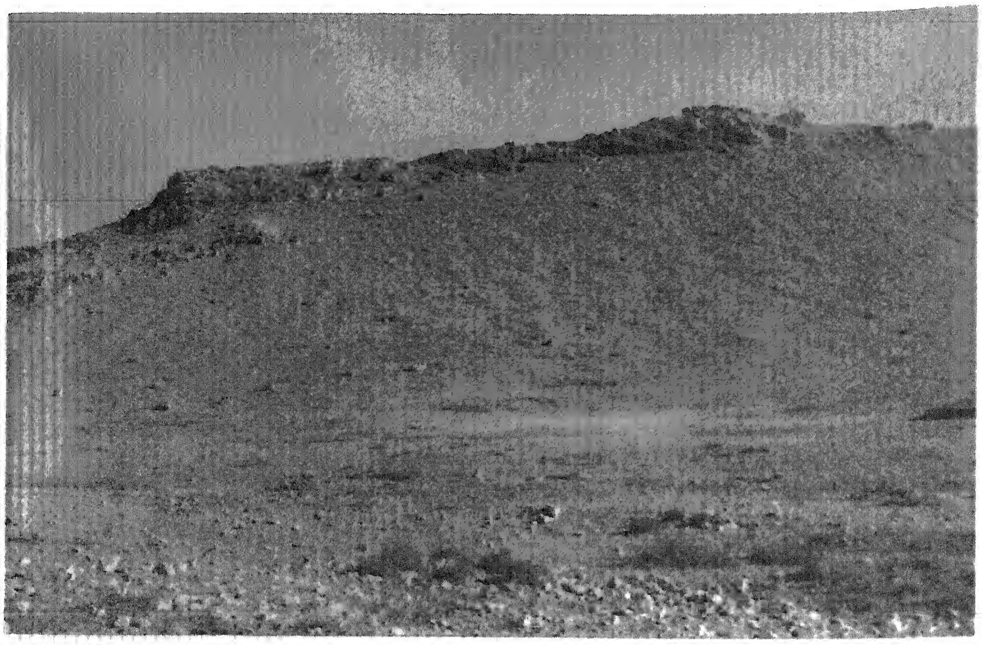


Fig. 32 : Barren hills

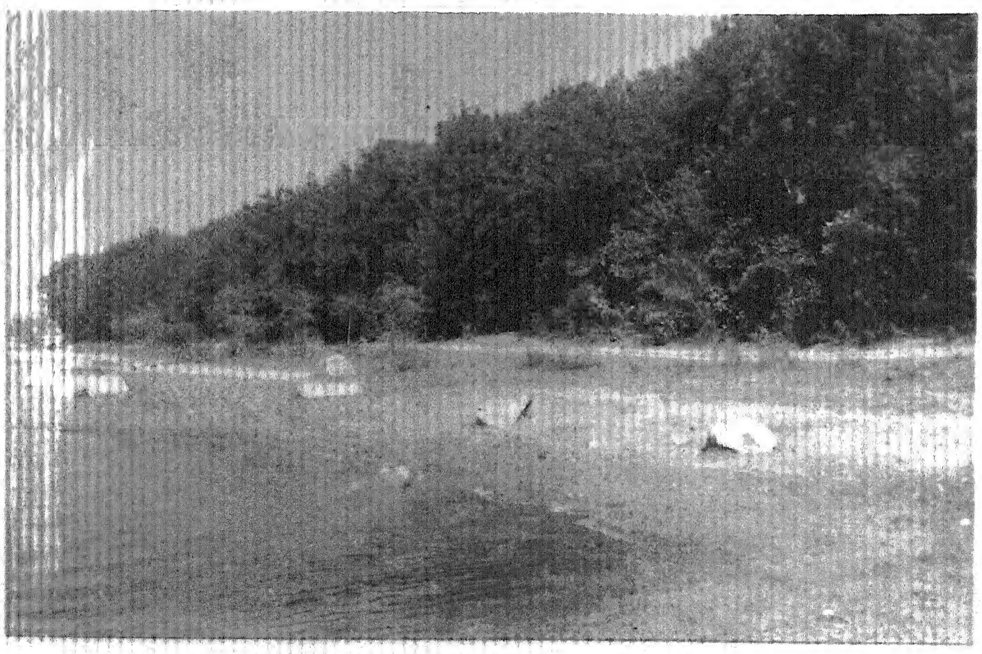


Fig. 33 : Subabool (*Leucaena leucocephala*) - the most important multipurpose tree for afforestation

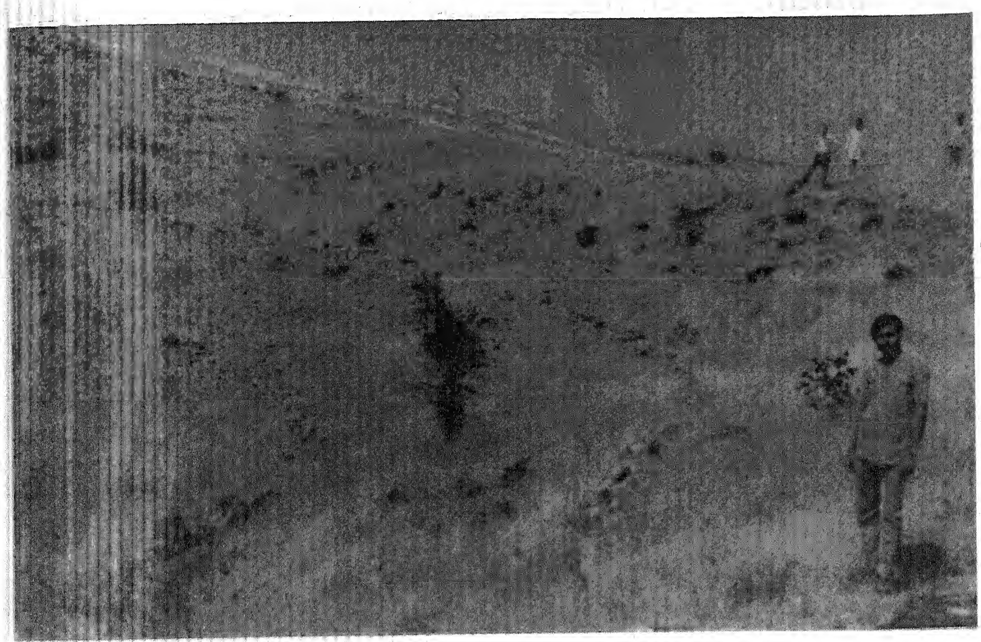


Fig. 34 : Contour stone ridges for moisture conservation for pasture development

Fig. 35 : Hill slope after two years of treatment that results in the profuse natural regeneration of grasses and luxuriant growth of *Leucaena leucocephala*

Fig. 36 : Acacia catecheu - A high value shrub for the regenerated hills

Fig. 37 : Extent of leaf litter on regenerated hills

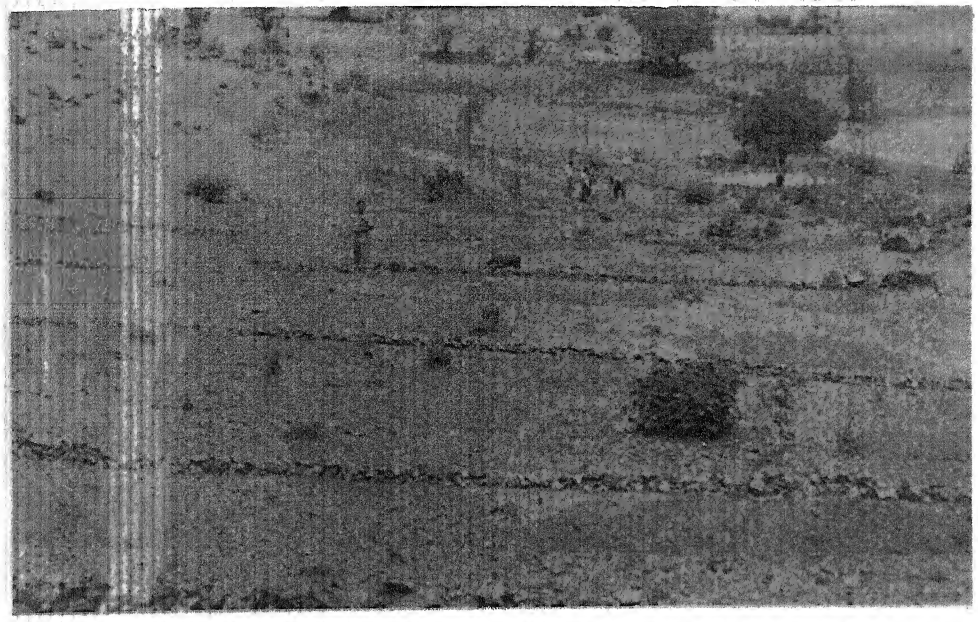


Fig. 38 : A view of soil working done that includes continuous contour ridges 3m apart and contour trenches 3m x 45cm x 40cm spaced 3m x 3m

Fig. 39 : The same area after one year of protection shows excellent cover of natural grasses. Note the growth of direct seeded *Stylosanthes hamata* in the trenches

4.4.5 Growth studies of trees

The studies on growth and performance of different tree species in the watershed indicated that among ten tree species, *Leucaena leucocephala* (Subabool) recorded very fast and maximum growth rate having 9.5 m (height), 15.6 cm (collar diameter), 13.2 cm (diameter at breast height) and crown diameter of 4.5 m, after five years of planting, followed by *Eucalyptus* hybrid, *Albizzia lebbeck, Albizzia procera,* and *Azadirachta indica* (Table 57). *Acacia catechu* registered least growth rate having 3.8 m (height), 6.8 cm (collar diameter), 5.9 cm (DBH) and clear bole length of 1.8 m, however, its highest survival rate (95%) indicates a good promise particularly for afforestation.

Table 57 : Survival per cent and growth performance of some of the planted tree species after five years

Tree species	Survival (%)	Height (m)	Collar Diam-eter (cm)	Diameter at Breast Height (cm)	Crown Diameter (m)	Clear bole Length (m)
Azadirachta indica	88	4.2	8.1	6.9	1.8	2.2
Albizzia lebbeck	92	5.8	10.3	8.8	3.5	3.8
Albizzia procera	89	5.0	9.5	8.3	3.0	3.6
Albizzia amara	88	4.6	7.9	6.8	2.9	2.2
Acacia nilotica	93	4.3	7.7	6.0	2.4	3.0
Acacia catechu	95	3.8	6.8	5.9	2.3	1.8
Dalbergia sissoo	82	4.1	7.2	6.0	1.8	2.2
Leucaena leucocephala	93	9.5	15.6	13.2	4.5	4.3
Embelica officinalis	92	3.9	7.0	6.1	2.0	2.2
Eucalyptus hybrid	92	8.8	14.8	13.5	2.2	5.0
CD 5%	N.S.	0.34	1.01	0.43	0.16	0.21

4.4.6 Fodder & fuel availability

The data on total fuel (firewood, cowdung cake and crop residues) and forage availability in the watershed during pre-and post-project phases are set out in Table 58 and 59, respectively. The survey revealed that the energy consumption pattern desired by the villagers is inconsistent with the available energy resources. It has been observed that the fuel consumption pattern which the villagers would like to have varies from the actual position. During the

pre-project phase 87 per cent of the total energy needs of the households were met from cowdung cakes, whereas, firewood and crop residues contributed only 7 and 6 per cent, respectively. The fuel consumption pattern changed dramatically during the post-project phase when consumption of firewood and crop residues went up to 28 and 10 per cent, respectively. The use of cowdung as fuel was reduced to 62 per cent, thus enabling the farmers to divert substantial quantity (995 tonnes) of the much needed cowdung to crop lands as manure. Firewood availability increased substantially from 70 to 568 tonnes/year leaving behind only deficit of 100 tonnes/year (Table 58).

Forage availability in the watershed increased by 4.6 times (Table 59) which not only met the total requirement but also recorded a surplus amount of 2872 tonnes/year.

Table 58: Fuel need and availability from various sources at the watershed village

Fuel energy source	Before treatment		After treatment	
	In tonnes	In per cent	In tonnes	In per cent
Total calculated fuel requirement*	1002	100	1028	100
- Firewood	651	65	668	65
- Cowdung cake	251	25	257	25
- Crop residues	100	10	103	10
Total actual fuel availability	1002	100	2021	100
- Firewood	70	7	568	28
- Cowdung cake	872	87	1252	68
- Crop residues	60	6	201	10
Deficit (-)/Surplus (+)				
- Firewood	581(-)	89(-)	100(-)	15(-)
- Cowdung cake	621(+)	247(+)	995(+)	387(+)
- Crop residues	40(-)	40(-)	98(+)	95(+)

** Based on village survey*

Figure in paranthesis indicates per cent increase over initial availability.

Table 59: Availability and requirement of forage in the watershed village

Forages	Before watershed		After watershed	
	In tonnes	In per cent	In tonnes	In per cent
Availability	1080	66	4960	238
Requirement	1628	100	2088	100
Deficit(-)/ Excess(+)	548(-)	34(-)	2872(+)	138(+)

4.5 Livestock studies

The species of animals and their composition over the years are presented in Table 60. There is a tremendous shift in animal species composition over the years. Number of cows were reduced by 35 per cent and increase in number of she buffalo by 37 per cent. This has also reflected in overall annual milk production that is from 79205 litres to 125925 litres (Table 66) which otherwise means 60 per cent increase in production. The average milk production per animal was also increased by 67 per cent due to availability of good quality sufficient forages and also due to progressively change over to good breeds. There is also a sizeable increase in bullocks from 469 to 728, an increase by 55 per cent.

Table 60: Animal composition, lactating animals and milk production at Tejpura watershed

Species	Number		Milk (litre/day/animal)	
	Initial	After six years	Initial	After six years
Cattle				
Cow	139	90	0.9	1.5
Bullock	469	728	(125)	(135)
Calves	50	40		
Buffalo				
She buffalo	51	70	1.8	3.0
Bull	2	3	(92)	(210)
Calves	15	30		
Goat	90	50		
Sheep	78	20		

Figures in parentheses indicate total milk yield in liters/day in the entire watershed village.

4.6 Run-off and soil loss studies

The effect of regeneration of vegetation, alongwith soil and water conservation measures on hill slopes and barren hills/hillocks is clearly revealed by the data on percentage reduction of run-off water loss, soil loss and sediment yield presented in table 61. Run-off water loss has been efficiently brought down to 22 and 16 per cent of annual rainfall on barren hills/hillocks and foothills, respectively. Similarly, soil loss has been reduced drastically to 1.9 and 0.9 tonnes/ha/annum from barren hills/hillocks and foothills, respectively which accounts for reduction by 95 per cent. Sediment yield was also found to be reduced by similar magnitude (97%).

Table 61: Effect of soil and water conservation measures and regeneration of vegetation on hill slopes and in lands adjoinings foot hills on run off water loss, soil loss and sediment yield at Tejpura Watershed.

Characters	Before treatment	After treatment		
		First year	Second year	Third year
Run off water loss (%)*				
(a)Barren hills/hillocks	70	52	35	22
(b)Foot hills	48	30	23	16
Soil loss (tonnes/ha)				
(a)Barren hills/hillocks	41.0	18.5	9.5	1.9
(b)Foot hills	20.5	14.0	5.5	0.9
Sediment yield (m)	0.36	0.16	0.07	0.01

** Run off water loss is expressed as percent annual rainfall.*

In case of silvipasture with appropriate soil and water conservation measures reduced the runoff by 68 per cent and soil loss by 98 per cent after five years as compared to barren untreated hills. On arable lands, with soil and water conservation measures, the runoff was reduced by 66 per cent and soil loss by 83 per cent over cropped land without such measures (Table 62).

Table 62: Effect of vegetation and soil and water conservation measures on run off, soil loss, forage production and crop yield after seven years of treatment at Tejpura watershed

Land use/ Vegetation	Soil and water conservation measures	Run off (% of annual precipitation)	Soil loss (t/ha/yr)	Dry forage yield (t/ha)	Crop yield (t/ha)	Increase in yield due to soil and conservation (%)
Silvipasture						
Barren hills (18-40% slope)	No conservation measures adopted	72	39.8	0.16	-	-
Silvipasture on hills (18-40% slope)	**Conservation measures adopted**	23	0.9	4.86	-	2938
Arable land						
Cropped land (1-3% slope)	No conservation measures adopted	38	9.6	-	0.7	-
Cropped land (1-3% slope)	**Conservation measures adopted**	13	1.2	-	4.0	471

All the land use systems were gauged for run of and soil loss studies and results revealed that the initial runoff water loss which was to the extent of 78 per cent of rain water was drastically reduced to 22-28 per cent (Table 63). Similarly, the soil loss was also greatly reduced to 0.2-0.9 tonnes/ha/year from initial loss of 38 tonnes/ha /year after seven years period.

Table 63: Forage yield, soil physico-chemical properties and soil and water conservation as influenced by silvipastoral development in barren hillocks at Tejpura watershed after seven years.

Soil properties	Silvipasture			Pasture	Initial status
	Leucaena leucocephala	*Acacia nilotica*	*Albizzia lebbeck*		
Organic carbon (%)	1.07	0.80	0.83	0.78	0.22
Available nutrients (kg/ha)					
N	302	263	282	231	87
P	22.5	15.8	16.5	13.9	6.3
K	308	287	283	268	189
S	39	22	24	18	4
Bulk density (g/cc)	1.29	1.33	1.33	1.38	1.68
Pore space (%)	50.4	48.9	48.9	47.0	36.0
Water stable aggregates (0.25 mm, %)	36	30	31	28	11
Field capacity (%)	16.6	16.0	16.1	15.3	11.2
Run off water loss (%)	22	26	26	28	78
Soil loss (t/ha/year)	0.2	0.4	0.4	0.9	38
Dry forage yield (t/ha)	5.1	5.9	6.2	6.7	0.1

4.7 Soil Productivity studies

The soil fertility build up under shilvipasture was greatly appreciated in five years period compared to barren hillocks. The average gain of nutrients were 112, 8.5, 8.6 and 15.5 kg/ha for N,P,K and S, respectively (Table 64). Similarly, the soil fertility was also appreciated in arable land due to adoptation of soil and water conservation measures. The fertility grains were 22, 3.5, 39 and 4.5 kg/ha for N, P, K and S, respectively (Table 64).

Table 64: Effect of vegetation and soil and water conservation measures on soil fertility build up at Tejpura watershed after six years of treatment

Land use/ Vegetation	Soil and water conservation measures cm)	pH	EC (mmhos/cm)	Organic carbon (%)	Available nutrients (kg/ha)			
					N	P	K	S
Silvipasture								
Barren hills (18-40% slope)	No conservation measures adopted	7.4	0.19	0.18	93	7.3	101	2.8
Silvipasture on hills (18-40% slope)	**Conservation measures adopted**	6.8	0.13	0.80	205	15.8	187	18.3
Arable land								
Cropped land (1-3% slope)	No conservation measures adopted	7.1	0.41	0.40	139	10.3	128	7.3
Cropped land (1-3% slope)	**Conservation measures adopted**	7.0	0.30	0.61	161	13.8	167	11.8

The study relating to different tree based silvipastures against pure pasture indicated that the silvipasture maintained a much higher soil fertility build up in seven years period than pasture (Table 63). Amongst the trees, *Leucaena leucocephala* was much better in this regard. All silvipastures and pastures has a great contribution in improving the overall soil fertility build up and improvement in soil physical properties over initial status.

The soil fertility under arable lands in different soil types had also indicated a significant improvement in organic carbon and available nutrients status (N, P,K and S) after six years (Table 65).

Table 65: Physio - chemical properties of the soil of the cropped area before and after six years of the watershed treatment at Tejpura watershed

Soil properties	Loamy sand		Sandy clay loam	
	Before watershed	After six years	Before watershed	After six years
Organic carbon (%)	0.17	0.57	0.24	0.69
Available nutrients (kg/ha)				
N	138.0	178.0	143.5	192.0
P	8.9	12.1	11.2	14.4
K	197.0	210.2	195.0	215.0
S	4.7	10.5	10.2	18.0

4.8 Socio-economic studies and other associated changes

4.8.1 Overall productivity

The watershed treatment over the years has resulted in continuous improvement in the productivity of all field crops (Table 66). Most significant about the crops was the sizeable increase in the total production of oilseeds from a meagre 5 to 180 tonnes. Similarly, pulses from 60 to 400 tonnes and cereals from 243 to 1900 tonnes. There was no vegetable production in the watershed area which rose remarkably over the years to a present level of production of 650 tonnes annualy. Total forage production was also increased from 1080 to 4960 tonnes, an increase by 359 per cent. Fuelwood production was also substantially

increased from 52 to 110 tonnes, an increased by 111 per cent. Milk production was increased from 79 to 126 tonnes, an increased by 59 percent. The check dams of the watershed were utilized for fish production for 6-8 months (August to March). The uppermost check dam which has a larger water body and stores about 10 ha m of water was put under composite seedlings like *Mirgal, Rohu* and *Katla.* In the year 1990-91 which was incidently the first year, there was harvest of about one tonnes of fish in a period of about 7-9 months fetching about Rs. 15000/-. This money was also utilized by the village Resource Management Committee (VRMC) for the village development work. The benefit from fish production is also accrued to the families engaged in fishing numbering 15 in the watershed. The auction is made to these people who in turn take care of the fish production and fulfill their partial living from this activity.

All these increased production lead to increase in total annual gross income from initial Rs. 19.68 lakhs to Rs. 134.2 Lakhs in the watershed area after five years, a spectacular increase by about 7 times (Table 66).

Table 66: Annual production of food crops, forages, fuelwood, milk and fish and gorss income from the produce at Tejpura watershed

Commodity	Prior to watershed (1982-83)		After five years of watershed development* (1990-91)	
	Production (tonnes)	Gross income ('000 Rs)	Production (tonnes)	Gross income ('000 Rs.)
Cereals	243	656	1900	5110
Pulses	60	430	400	2850
Oilseeds	5	50	180	1289
Vegetables	-	-	650	975
Forages	1080	540	4960	2480
Fuelwood	52	21	110	44
Milk	79	271	126	657
Fish	-	-	1	15
Total	1519	1968	10295	13420

The wateshed treatment was completed in 1985-86

4.8.2 Employment generation

The important aspect that needs to be considered in the overall impact of the watershed for the rural poor is the employment generation for these people. There were 35 landless farm families in the watershed which consituted about 8 per cent of the population and there were 195 families (43% of the population) which were below poverty line. The human employment which have generated over the years is indicattive of the significant impact of the watershed for rural poor which consitutued about half of the beneficiaries (Table 67). The increase in human employment was to the tune of about 3.1 times increase over the base year and the bullock days were also of similar magnitude.

Table 67: Employment generation over the years at Tejpura wateshed

Year	Human labour (Man days)	Bullock labour (Bullock days)
1982-83	41515	30590
1985-86	96520	71120
1988-89	116280	85680
1990-91	127200	92260

4.8.3 Benefit-cost of watershed

The life period of soil and water conservation work was taken as 10 years although after ten years period not a single structure was broken in the watershed. The overall benefit-cost ratio as worked from individual activities and itemwise cost is presented in Table 68. This indicates the benefit-cost ratio as workedout after the completion of watershed work during 1985-86 was 2.71. Additional expenditure was worked out to be 14.08 lakhs against an additional gain of 52.3 lakhs. Total amount spent for the development of the watershed was Rs. 35.5 lakhs which worked out to be Rs. 4586 per hectare. The per cent cost of individual activities were 52 on soil and water conservation, 33 on improved cropping, 2.5 on pasture development, 0.5 on afforestation and 12 per cent on establishment.

Table 68: Overall benefit - cost ratio from direct produce at Tejpura watershed on the basis of 1985-86

Description	Area (ha)	Additional expenditure		Value of additional produce	
		Rate (Rs/ha)	Total (Rs)	Rate (Rs/ha)	Total (Rs)
Soil and water conservation work	760.6	243.2*	184978.00	-	-
Improved cultivation practices	650.0	1800.00	1170000.00	7800.00	5070000.00
Pasture grasses	109.4	81.0*	8860.00	1134.00	124000.00
Afforestation	36.0	55.0*	1980.00	1000.00	36000.00
Establishment	775.0	53.0	42625.00	-	-
Total	-	-	1408443.00	-	5230000.00

Benefit-cost ratio = (52.30-14.08)/14.08 = 2.71

*** Calculated on the basis of 10 years life.**

Fig. 40 : A family - happy with good tamato harvest

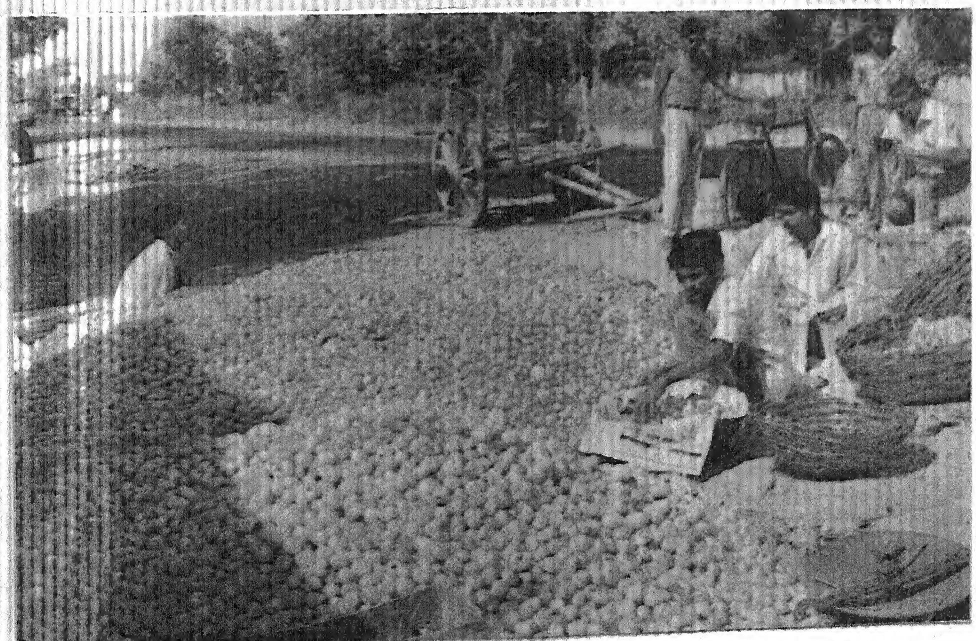


Fig. 41 : Farmer's cooperative - packing and marketing of tomatoes

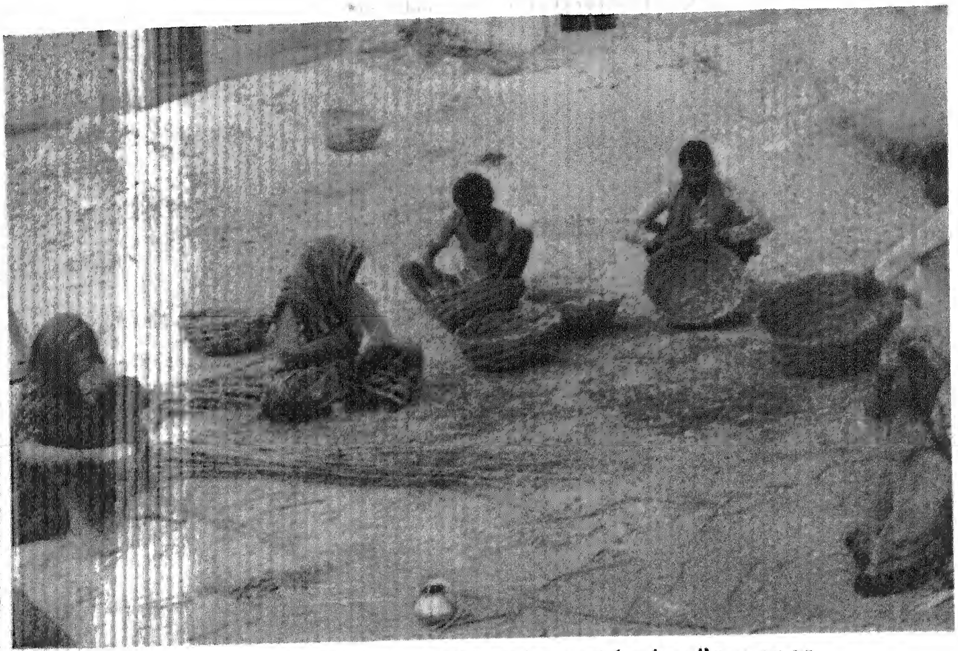


Fig. 42 : Basket making - self emploment for landless poor

Fig. 43 : Marketing of basket by rural poors

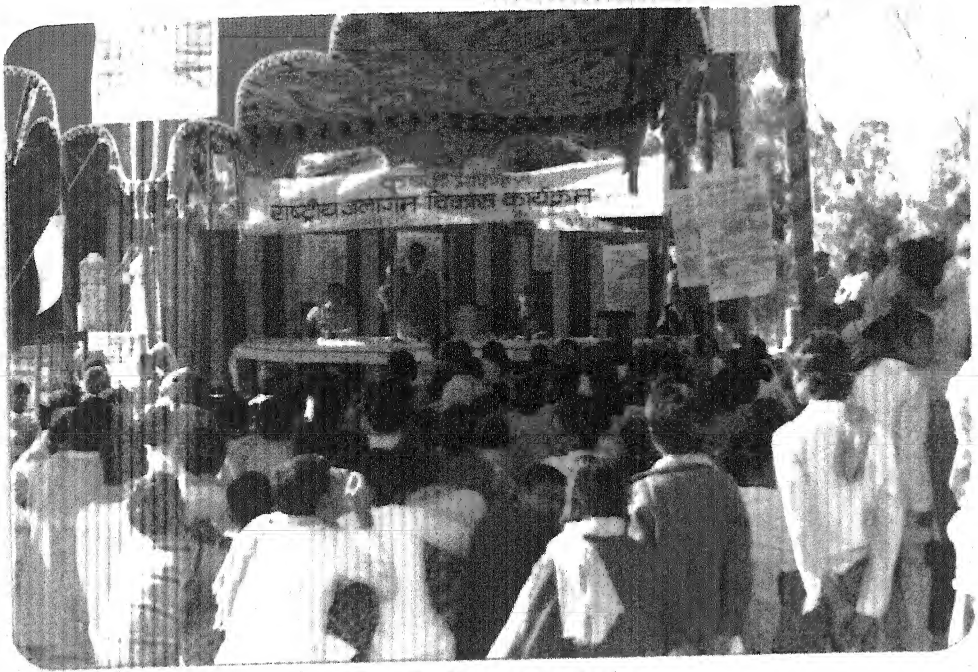


Fig. 44 : Farmer's training

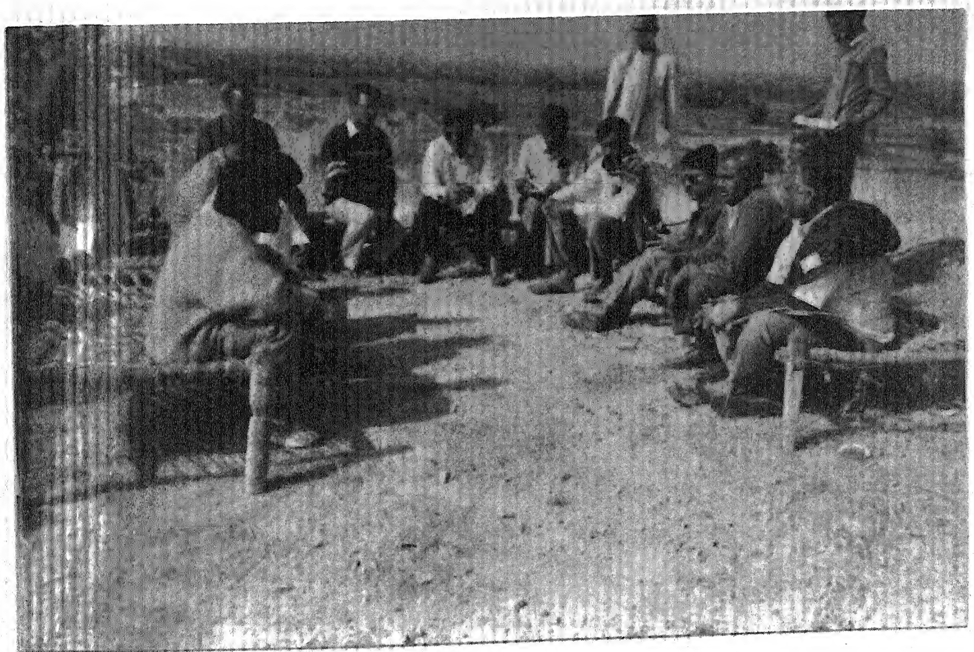


Fig. 45 : A Kissan gosthi

CHAPTER-5

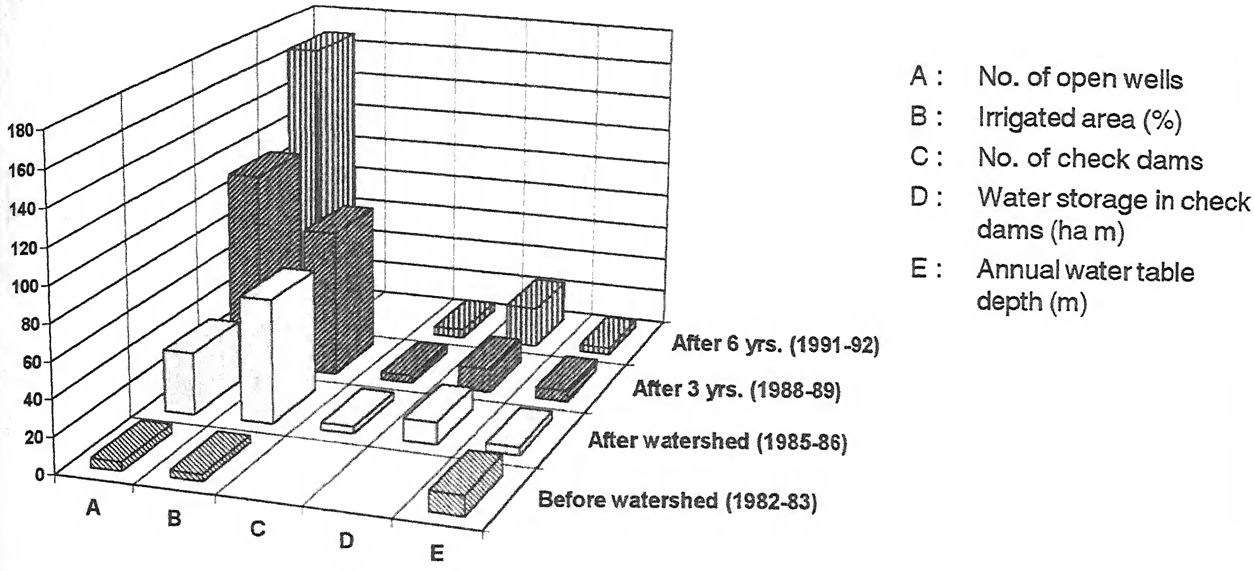
SUMMARY & CONCLUSIONS

Summary and conclusions

The present investigation entitled "Integrated natural resource conservation on watrshed basis for increasing productivity" conducted at Tejpura watershed, which is located at 45 km south-east Jhansi township covers an area of 775.7 ha. The upper reach of the watershed is bounded by small hillocks closely located to Madhya Pradesh state in the southern side from where a small rivulets with width of 6-10 m flows through the entire length of the watershed (6.5 km) in a 'L' shaped form. At the head of the watershed there are two deep gullies join the rivulet named as kharaiya nallah. The watershed is virtually divided in to five micro-watersheds on the basis of natural drainage. The soil of the watershed varies from loamy sand to sandy loam on the upper reaches with average slope varying from 3 to 5 per cent and on the lower reaches with soils of clay loam to silty clay loam and slopes of 1 to 3 per cent. The area receives an average rainfall of 940 mm and has potential evapotranspiration of 1520 mm. The crop productivity of the area before the watershed project intervention was 0.6 t/ha and actual cropped area was 436.8 ha out of the total cultivated area of 525.6 ha. The cropping intensity was 82 per cent with only 3.8 per cent area under irrigation. The watershed covered 450 farm families of which 195 were below poverty line and 35 were landless.

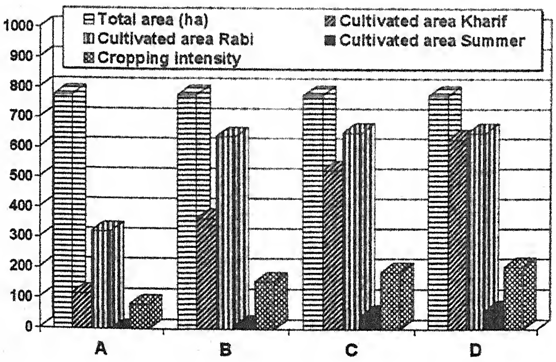
Appropriate soil and water conservation measures were adopted in the watershed area fror controlling soil and water loss, in-situ conservation of rain water and ground water recharge. About 23 ha m of rain water was stored in 5 check dams, biggest one being the water harvesting dam having storage capacity of 10 ha m, which resulted in rise of ground water table by 3 to 8.5 m and this increased underground water lead to the digging up of wells from 5 in number to present number of 167. This reflected in incresed irrigation to crops from initial 3.8 per cent area to present 92 per cent area (Fig. 46) and also increased cropping intensity of 206 per cent from initial 82 per cent*. This helped in increased annual productivity of crops (oilseeds from 5 to 180 tonnes, pulses from 60 to 400 tonnes, cereals from 243 to 1900 tonnes, and vegetables from 14 to 650 tonnes), forage (from 1080 to 4960 tonnes), fuelwood (from 52 to 110

** as well as crop productivity (Fig. 47)*

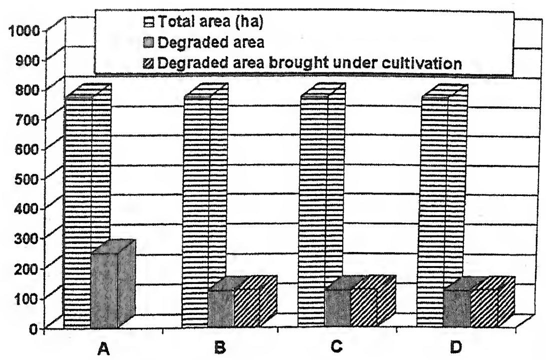


Water resource development

A : Before watershed (1982-83)
B : After watershed (1985-86)
C : After 3 years (1988-89)
D : After 6 years (1991-92)



Land use pattern (cultivated)



Land use pattern (degraded)

Fig. 46 : Water resource development and land use pattern at Tejpura watershed

A : Area (ha) before watershed (1980-83)

B : Productivity (q/ha) before watershed (1980-83)

C : Area (ha) after watershed (1991-92)

D : Productivity (q/ha) after watershed (1991-92)

E : Increase in productivity (%)

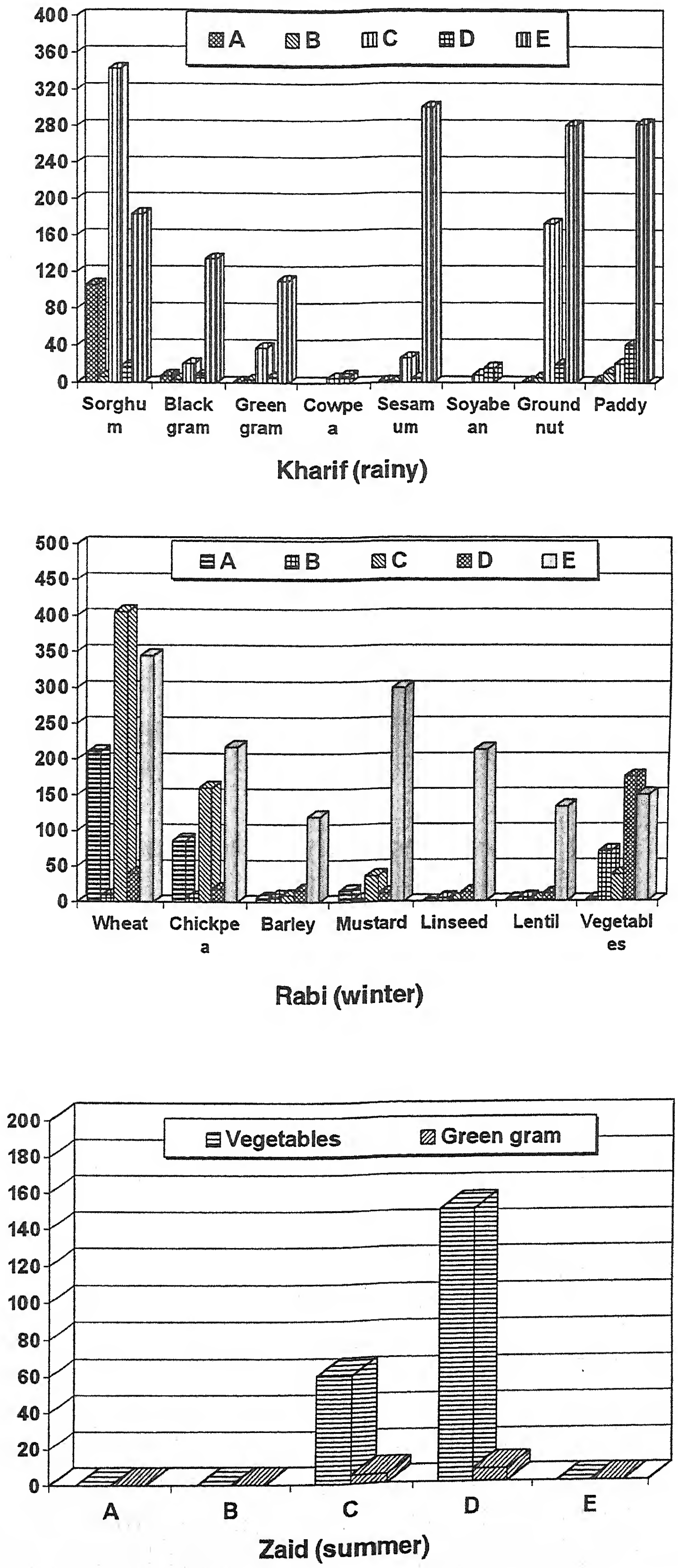


Fig. 47 : Change in area and average productivity of principal crops as influenced by watershed management at Tejpura

tonnes), milk (from 79 to 126 tonnes) and fish (from nil to 1 tonne) and thereby increased total gross income by about 7 times over the base year within a period of only five years. Soil and water conservation measures greatly influenced in reduction of run off by 69 per cent and soil loss by 95.5 per cent, besides degraded land of 128 ha was brought back to cultivation. Silvipasture greatly helped in increased biomass production and rehabilitation of degraded lands. Employment opportunity to village poors was increased by more than three fold and benefit - cost ratio of the watershed programme was 2.7.

The presnet investiagion has developed a cost-effective integrated watershed management model for the development of rainfed agricultural lands and also the village common grazing lands including the degraded wastelands. This may not be taken as a rigid model that one should follow, but as a successful project, its findings could be exploited elsewhere for the development of watershed and greening of *Aravallis* and *Shivaliks*, which are also degraded and bereft of vegetation due to misuse, and where was shortage, both for drinking and for irrigation purposes is being keenly felt by the villagers. The project has also clearly demonstrated the existance of upland - lowland interaction in the vindhyan ecosystem and the development of one in isolation of the other will not succeed.

The major lessons learnt in implementing the present project are :

- close liaisoning is essential with the village community,
- confidence of the people should be earned,
- should not be aligned with any specific group or community or caste,
- villagers should feel that the programme is really meant for them and their society,
- participation of villagers at each and every stages of programme is essential so that they have a feeling for sense of belonging to the programme,
- no section of the society should feel isolated, ignored and less important,
- adequate attention is to be given in generating all sorts of possible employment opportunities particularly for the village poors and landless, which keeps small ruminats for subsistence living, that causes incalculable damage to natural vegetation due to free ranging. All disputes should amicably be settled at the village level through discussion and persuation.

Conculsion

Development of land on integrated watershed approach takes care of all round development of village community through their intimate involvement and participation in the programme. The programme offers a great opportunity to the researchers to generate scientific informations of varied nature and appraisal and feed back on technology transfer and adoption by the farmers. This also provides and opportunity for 'on-farm' studies and participatory rural appraisal. The programme of this kind also brings the researchers, development workers and the farmers to a much more closer working association and confidence building amongst themselves. The villagers/rural poors should be considered as partners and not as wage earners. To arm the villagers, the village level institution must be build which will ultimately take care of the newly created/regenerated resources including sharing of benefits, its sustenance and protection.

CHAPTER-6

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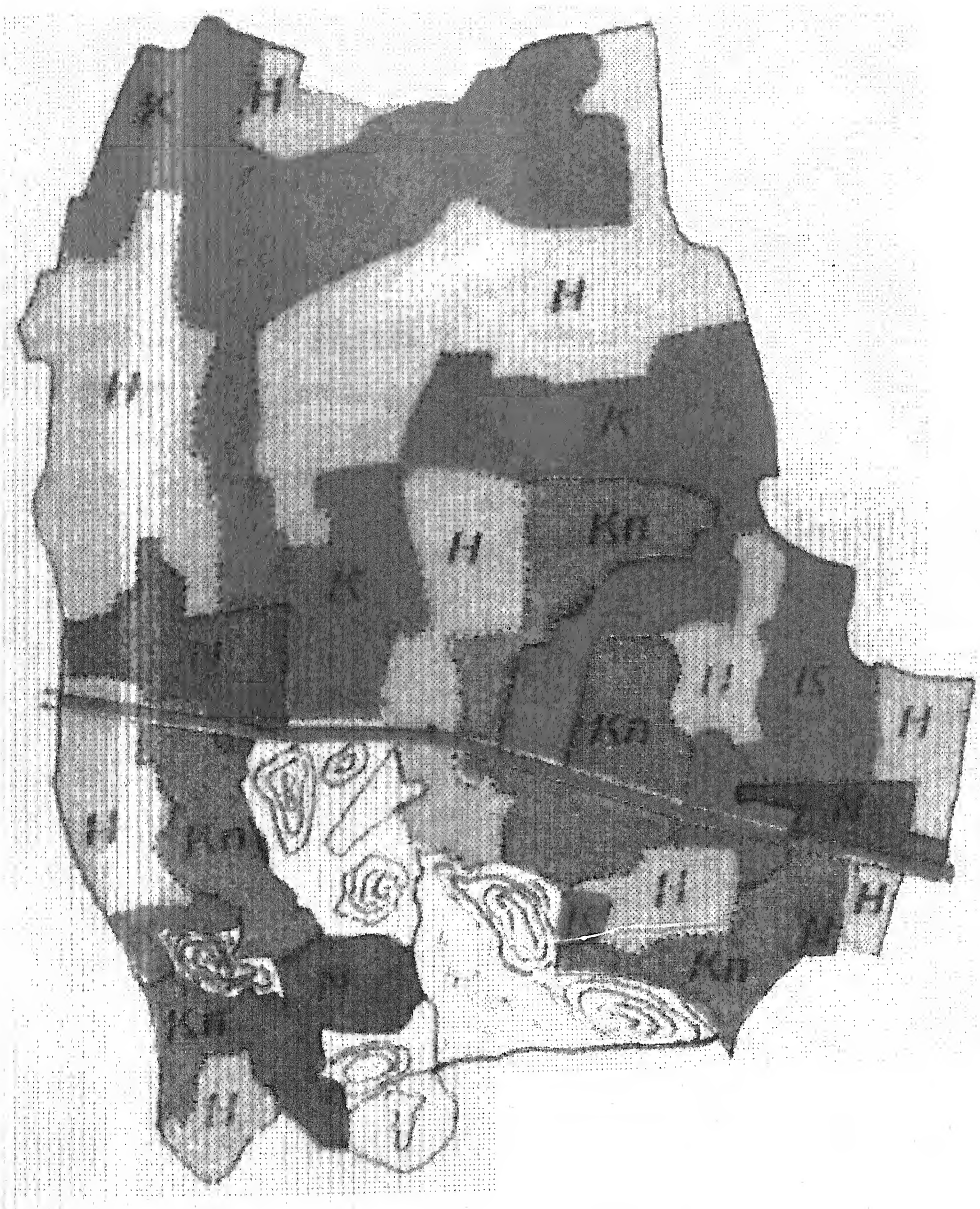
CHAPTER-7

APPENDICES

SOIL MAP
TEJPURA WATERSHED
JHANSI (U.P.)

SCALE 1"= 2420'



1- HARIPUR SOIL SERIES H

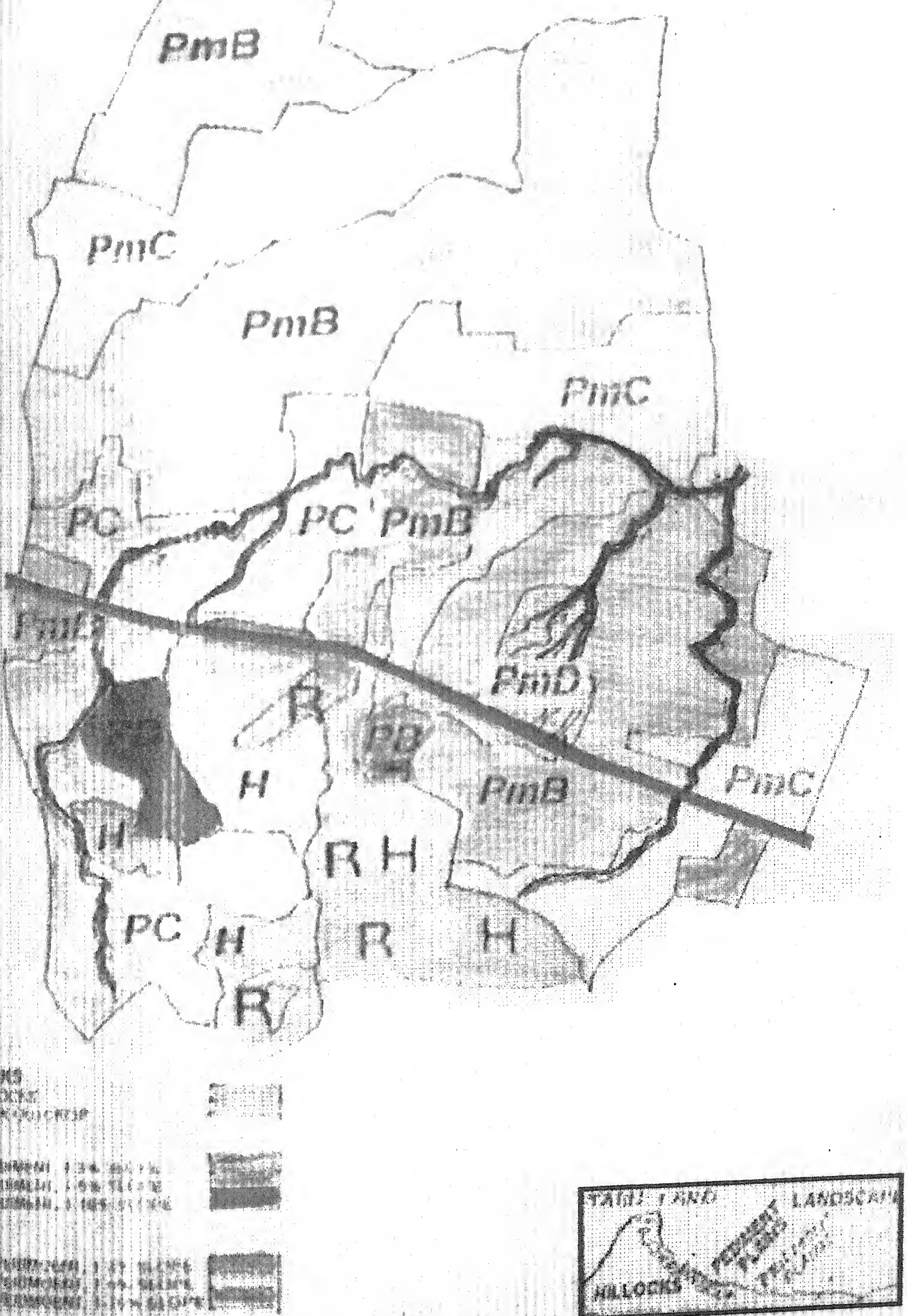
2- KHAIRAR SOIL SERIES K

3- KINDHAULI SOIL SERIES Kn

4- NAHARI SOIL SERIES N

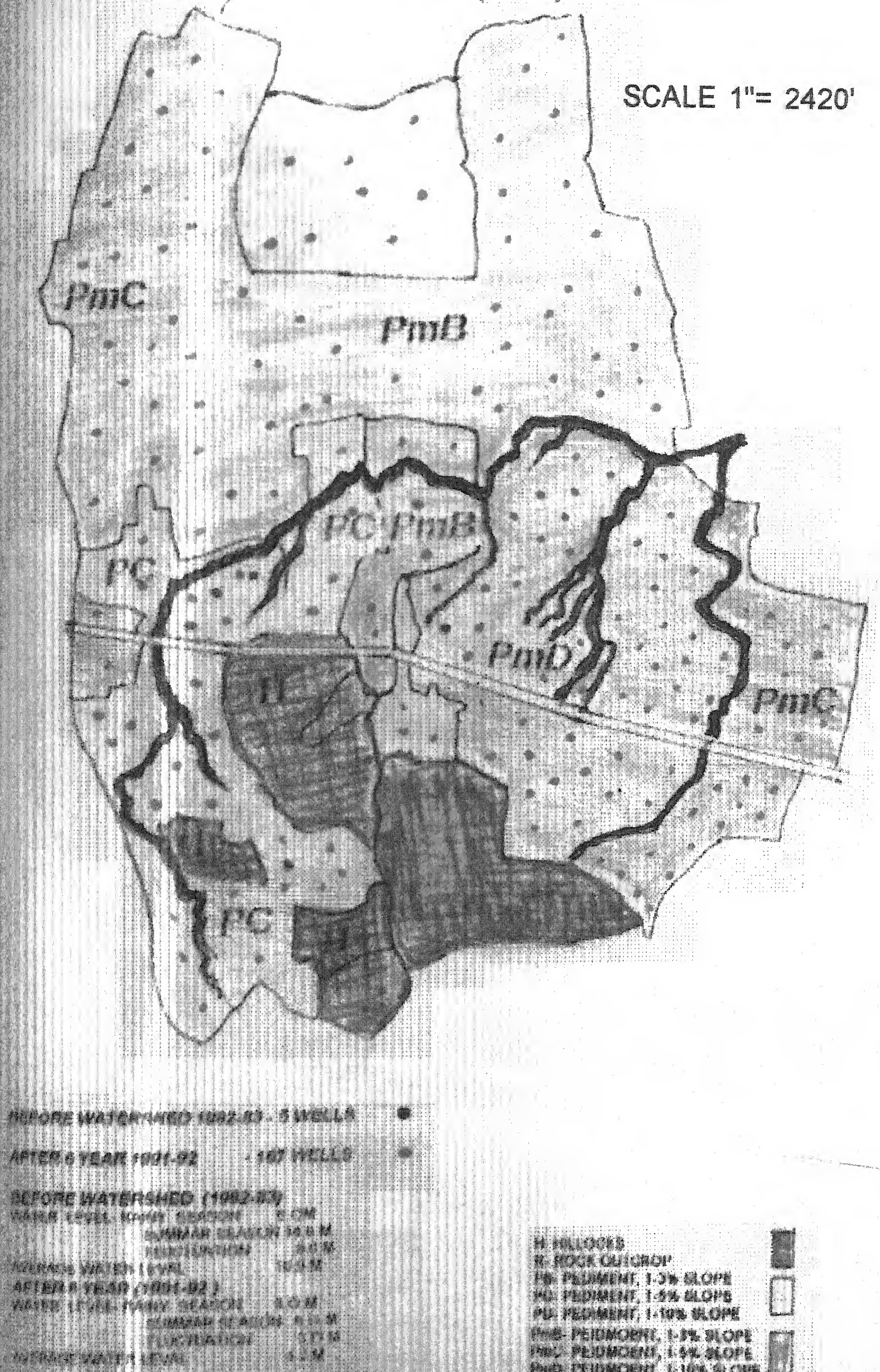
PHYSIOGRAFIC MAP
TEJPURA WATERSHED
JHANSI (U.P.)

SCALE 1"= 2420'



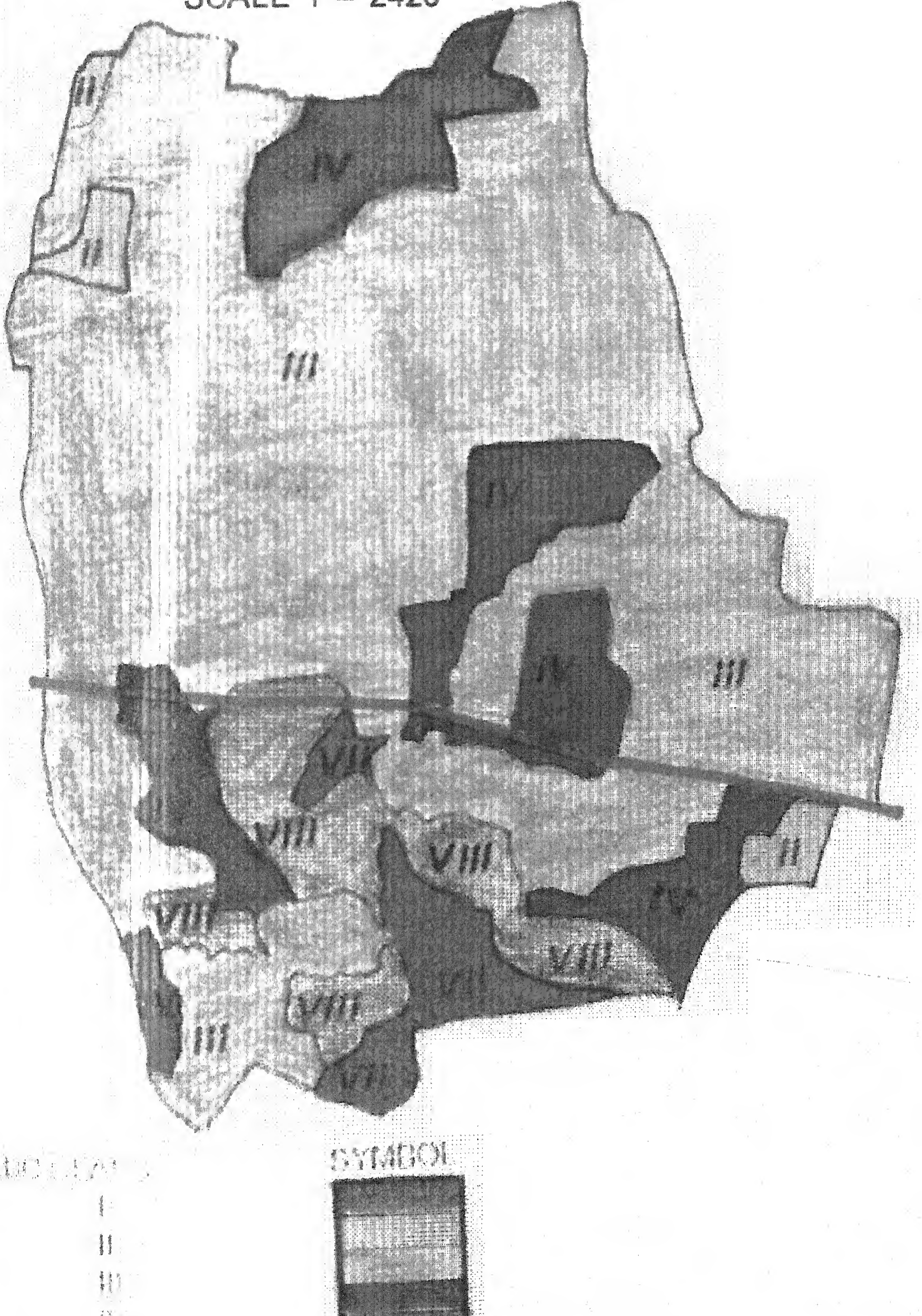
APPENDIX - 3

HYDROLOGICAL MAP
TEJPURA WATERSHED
JHANSI (U.P.)



LAND CAPABILITY CLASSIFICATION MAP
TEJPURA WATERSHED
JHANSI (U.P.)

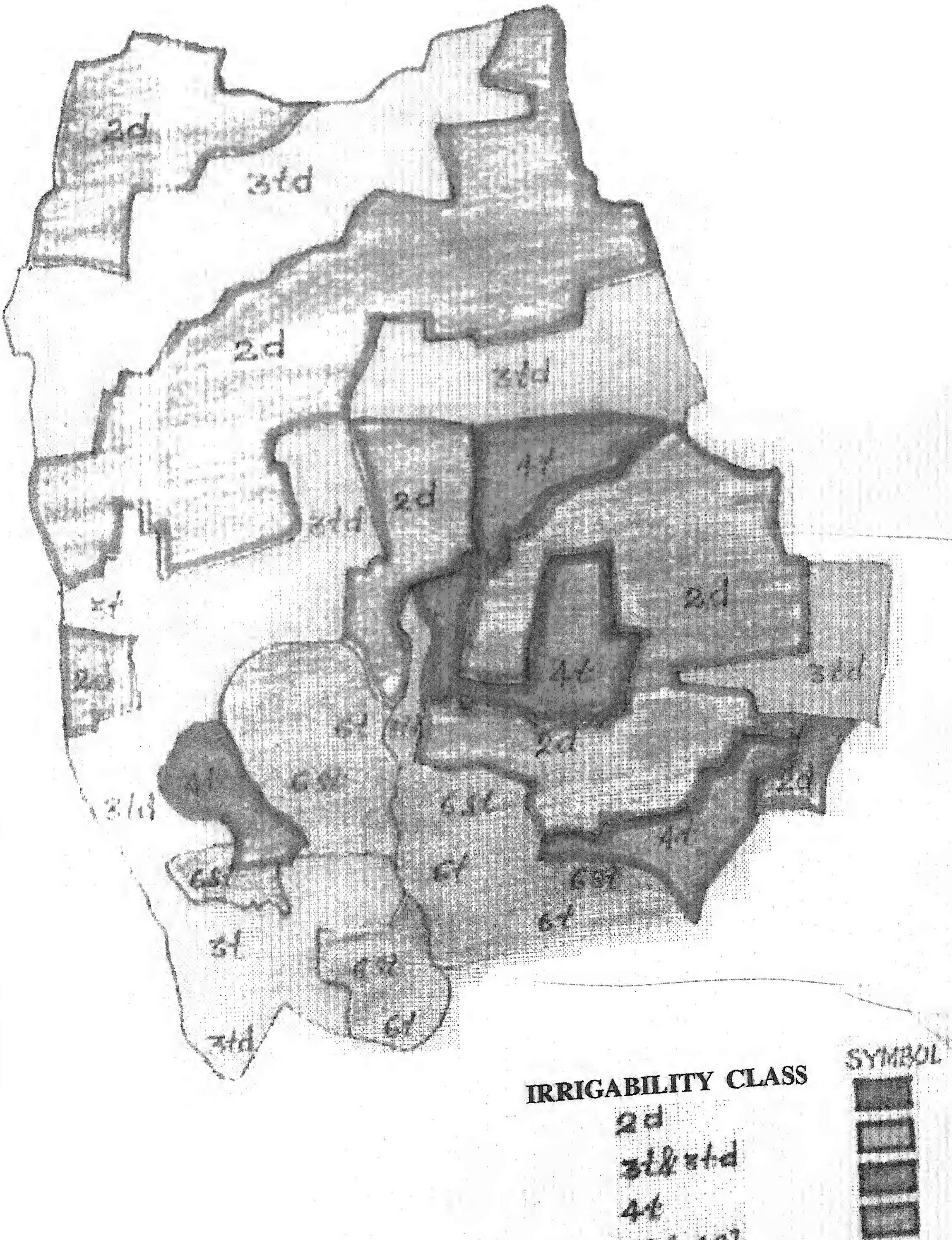
SCALE 1"= 2420'



APPENDIX - 5

LAND IRRIGABILITY CLASSIFICATION MAP
TEJPURA WATERSHED
JHANSI (U.P.)

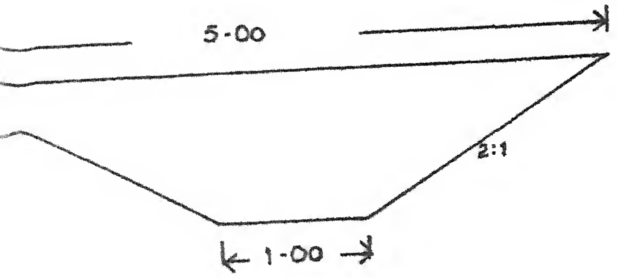
SCALE 1"= 2420'



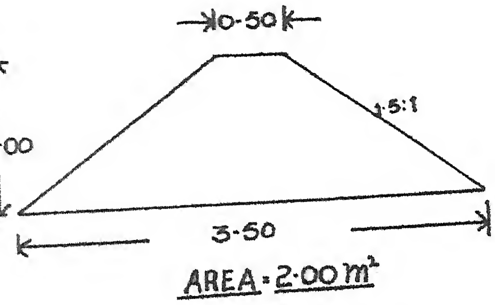
DETAILS OF DIVERSION CHANNEL

SCALE = 1CM=0.5M

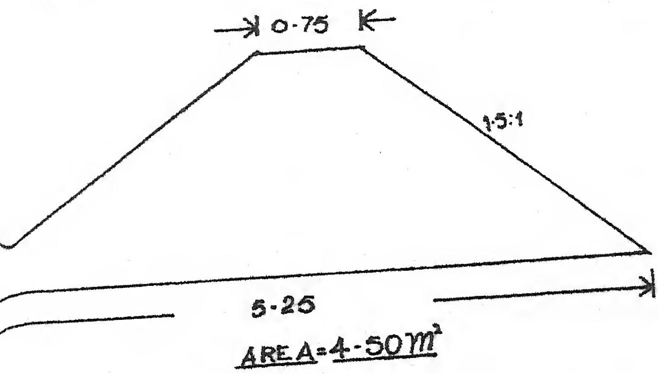
DEPTH OF FLOW..............0.7M
FREE BOARD....................0.3M
AVERAGE VELOCITY........1.5M/SEC.
DISCHARGE.............2.0475CUM/SEC.



DETAILS OF COTOUR BUND

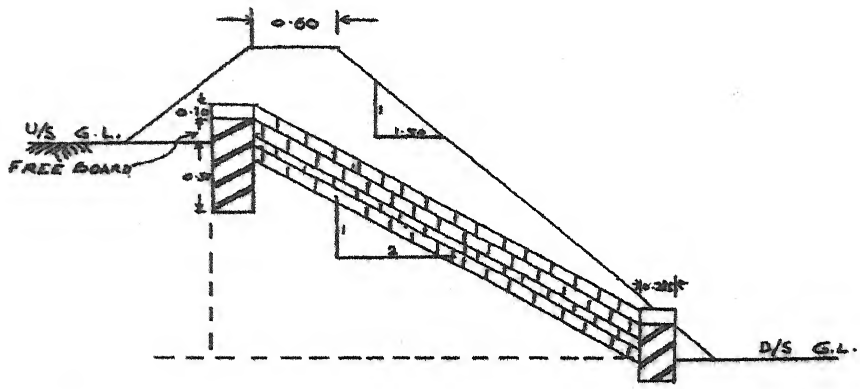


DETAILS OF SUBMERGENCE BUNDS

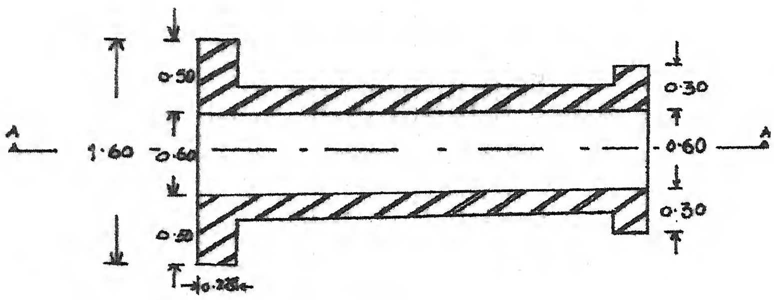


DESIGN OF CHUTE SPILLWAY

SCALE - 1CM=0.5M



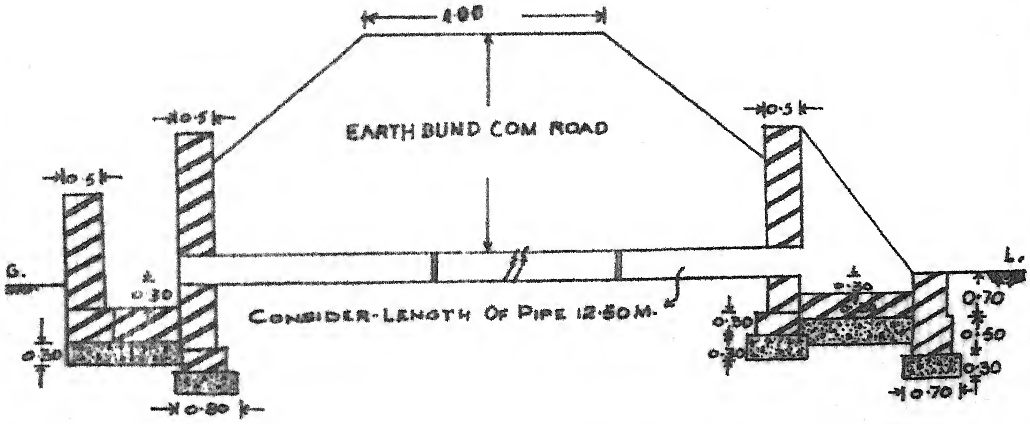
SECTION ON 'AA'



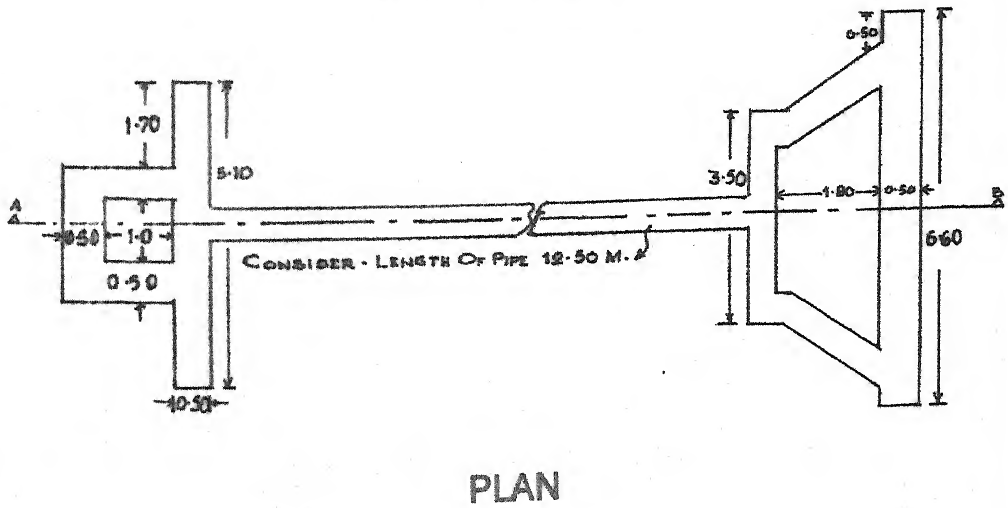
PLAN

PIPE DROP INLET

SCALE - 1CM=1M



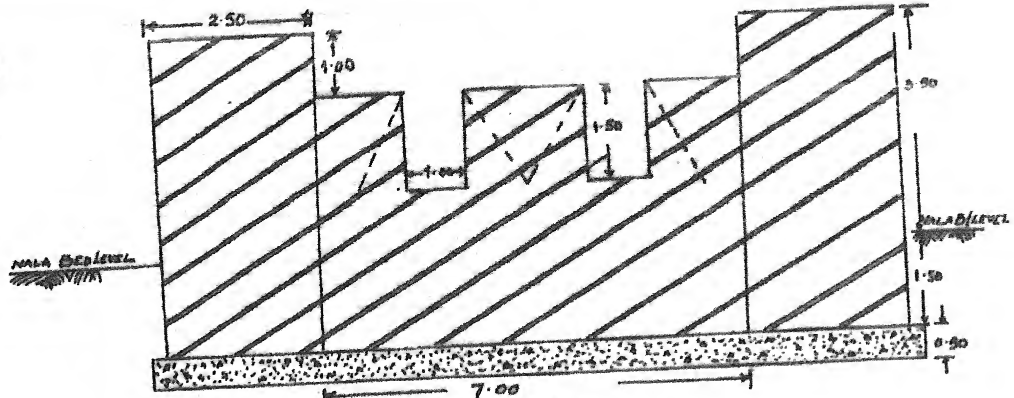
SECTION ON 'AB'



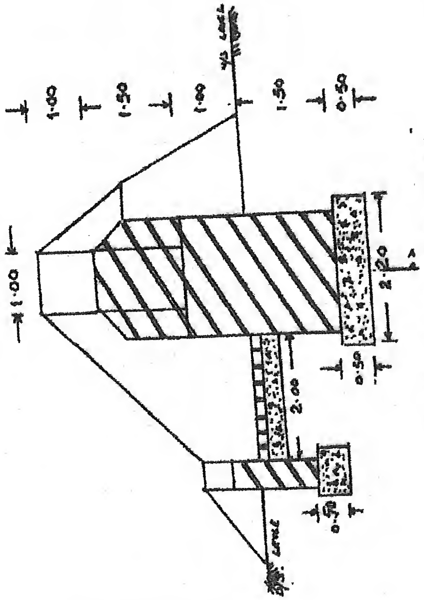
PLAN

DETAILS OF CHECK DAM

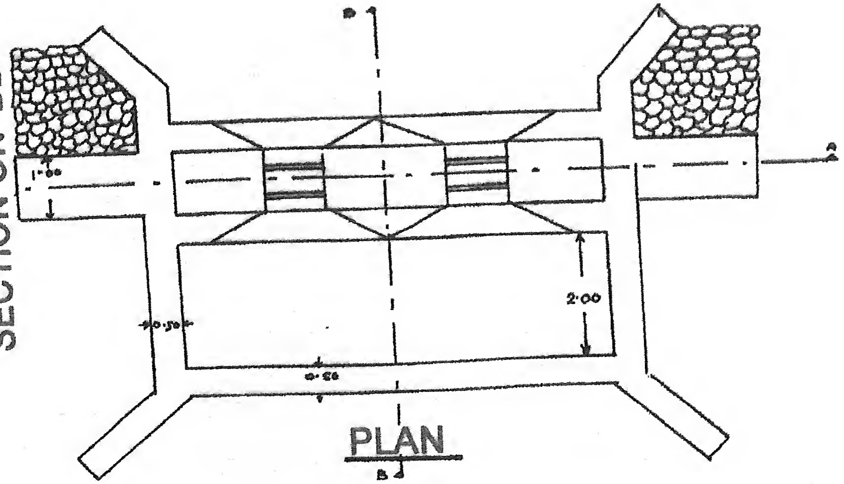
SCALE - 1CM=1M



SECTION ON 'AA'



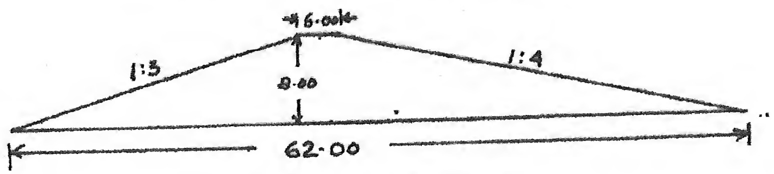
SECTION ON 'BB'



PLAN

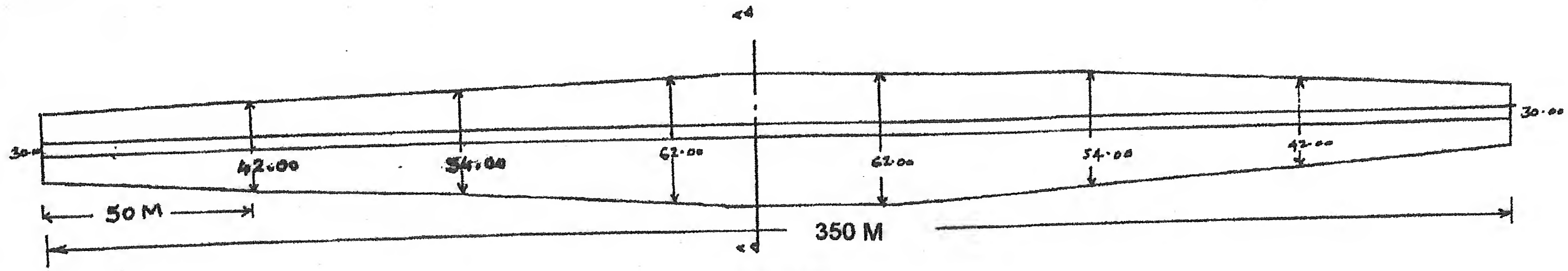
APPENDIX - 12

WATER HARVESTING DAM



SECTION ON 'AA'

SCALE - 1CM=5M

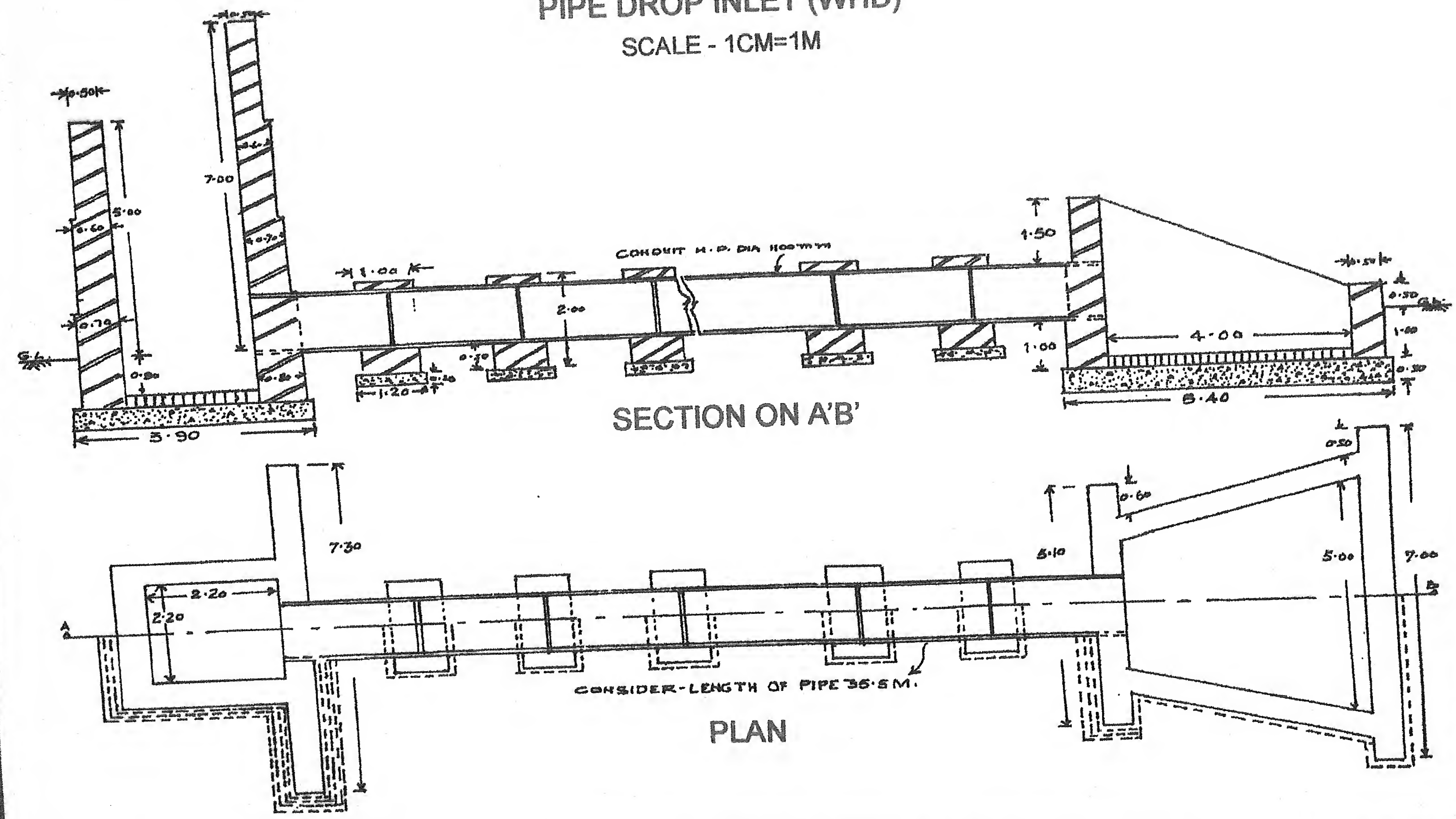


PLAN

SCALE - 1CM=30M (V)
1CM=15M (H)

PIPE DROP INLET (WHD)

SCALE - 1CM=1M

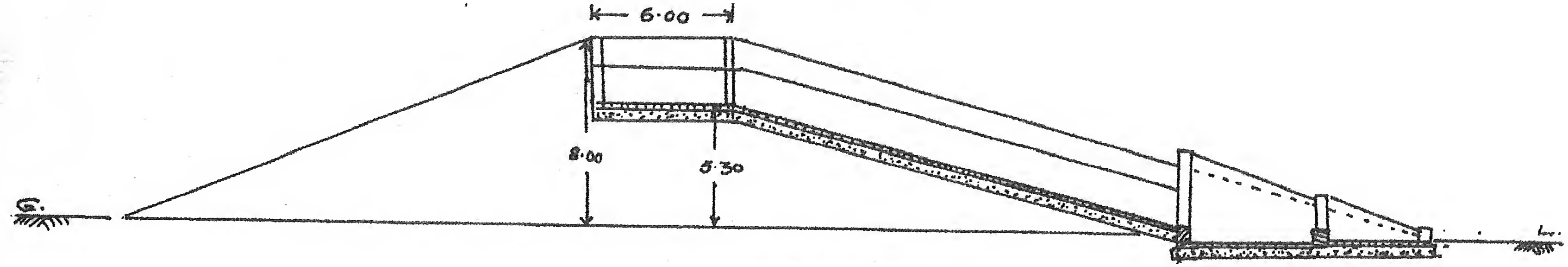


SECTION ON A'B'

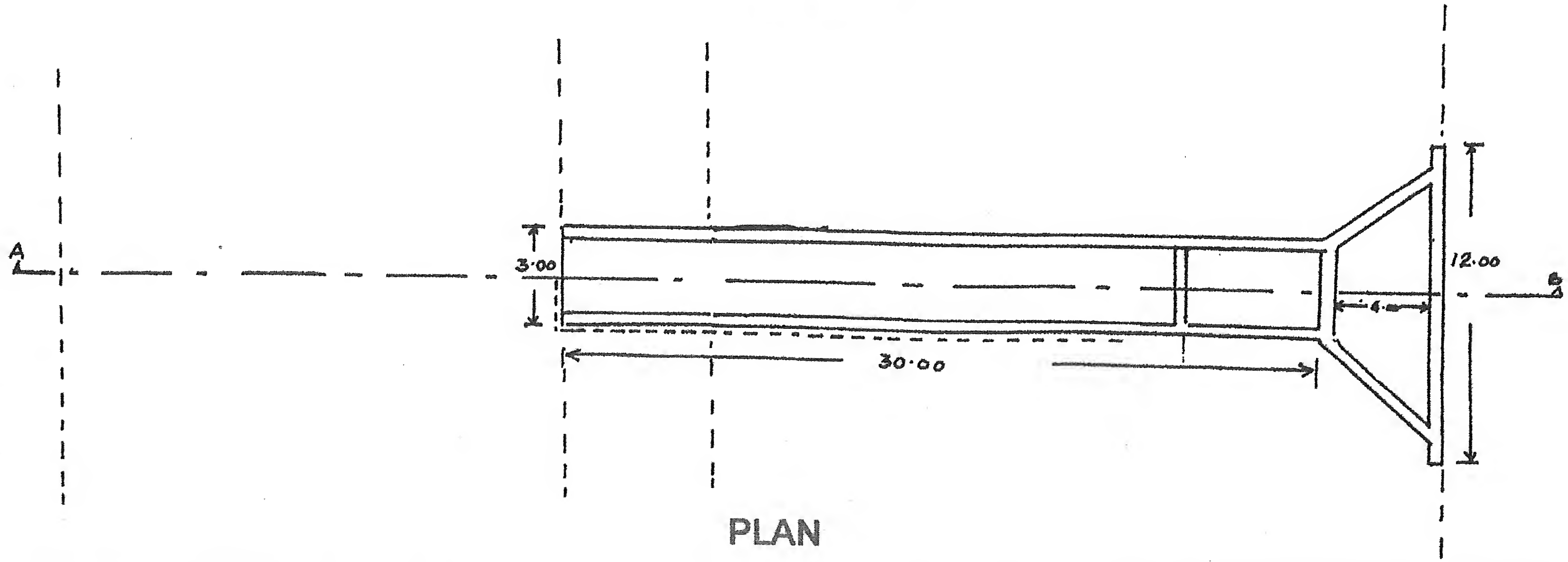
PLAN

DETAILS OF EMERGENCY OUTLET (WHD)

SCALE - 1CM=1M



SECTION ON A'B'



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